AD-754 445

ADVANCED MARINE TECHNOLOGY

A. E. Maxwell, et al

Woods Hole Oceanographic Institution

Prepared for:

Advanced Research Projects Agency
Office of Naval Research

30 November 1972

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TECHNICAL PROGRESS REPORT

ADVANCED MARINE TECHNOLOGY

1 August 1971 - 31 January 1972

November 30, 1972

Sponsored by
Advanced Research Projects Agency

ARPA ORDER NO. 293-008

Dr. A. E. Maxwell, Principal Investigator

Prepared for the Office of Naval Research under Contract N00014-71-C-0284; NR 293-008.

WOODS HOLE, MASSACHUSETTS 02543

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Woods Hole Oceanographic Institution Woods Hole, Massachusetts 02543	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

TECHNICAL REPORT

ADVANCED MARINE TECHNOLOGY

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Progress Report 1 August 1971 - 31 January 1972

5. AUTHOR(S) (Last name, first name, initial)

Thomas C. Aldrich, Robert D. Ballard, Carl O. Bowin, Bruce P. Luyendyk, William M. Marquet, Joseph D. Phillips, Gilbert T. Rowe, Kenneth L. Smith, John M. Teal, Elazar Uchupi, Allyn C. Vine, Richard P. von Herzen, Peter H. Wiebe, David L. Williams

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
November 30, 1972	66	

8a. CONTRACT OR GRANT NO. N00014-71-C-0284; NR 293-008	9a. ORIGINATOR'S REPORT NUMBER(S) WHOI-72-90
b. PROJECT NO. c. d.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

Approved for public release, distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office of Naval Research Ocean Science & Technology Division Arlington, Virginia 22217

13. ABSTRACT

This is a progress report for the period 1 August 1971 - 31 January 1972 on the following projects in Advanced Marine Technology: (a) Submerged Navigation and Submersible Instrumentation (development of precise navigation for a small submersible), (b) Handling and Transfer at Sea (use of energy absorbers in small boat and buoy handling alongside in rough weather), (c) Bottom Reconnaissance and Detailed Site Survey (use of submersible in geological mapping), (d) Near Bottom Magnetic Studies Using a Deep Submersible, (e) Near Bottom Gravity Studies from a Deep Submersible, (f) A Self-Contained Deep Sea Rock Drill, (g) Development of Equipment for Use in Deep Ocean Biological Research (observation and collection under pressure of benthic biology).

14 KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
1. Advanced Marine Technology						
2. ALVIN						
3. Navigation of submersible						
4. Transponders						
5. Boat Handling Buoys						
6. Small Craft						
7. Geological Mapping						
8. Gulf of Maine						
9. Geological Sampling						
10. Magnetometer (deep)						
11. Gravimeter (deep)						
12. Rock Drill						
13. Heat Flow						
14. Benthic Biology						
15. Biological (deep) Station						
16. Refraction						
17. Reflection						
18. Echo Ranging						

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WHOI-72-90

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Approved for Distribution E. Hays

Earl E. Hays, Chairman
Department of Ocean Engineering

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Report Summary

This program is increasing the efficiency of the use of submersibles, here at Woods Hole in particular, and at other submersible operating facilities. The submersible community is still so small that successful developments, and just as important, the unsuccessful, are known quickly through the community, so that there is little duplication of effort in development.

The two gross problems the small submersible has are: the launch and recovery in heavy weather, and a rather limited energy supply. Each of these problems requires a major effort.

There are however other problems of immediate interest and these are the ones on which we are working in the main.

Typically we find that progress is never as rapid as we wish it to be, however it does go forward, and ALVIN was a more capable submersible at the end of 1971 than it was in the beginning of the year.

It may be noted that Offshore Monitoring of Industrial Waste was completed in the first six months of this contract year and the six month report serves as the report on that project.

No activity has taken place in the Air-Seas Systems project because of scheduling difficulties with Navy Aircraft, so no six month report is included. The project has a tentative schedule for next year and we hope it can be carried out as planned.

(a) Submerged Navigation and Submersible Instrumentation

1. Purpose and Background

The objective of the submerged navigation development program is to develop and conduct at sea evaluations of an acoustic navigation system for submersibles and their support ships. The program began in February 1971. The first six months were spent detailing the basic real-time system, procuring the major components, building a prototype of the support ship master time controller and integrating the support ship system. This report covers the period 1 April 1971 through 31 January 1972 during which the system was debugged and tested at sea.

2. Sea Trials

During the reporting period 38 days were spent at sea. The primary goal of the sea trials was to demonstrate effective acoustic signaling between the submersible, bottom moored reference transponders and the support ship. During August and September thirteen days were spent at sea on R/V LULU cruises No. 46 and 47. During these cruises major difficulties were experienced. It was found that maximum acoustic signal-

ing distance at 15 kHz between the submersible and its support ship was 1500 yards. This is unacceptably short for open ocean work. Following these cruises an extensive set of tests were scheduled to re-measure various system parameters. It was found that there was a significant impedance mismatch at 15 kHz, caused by the transmit/receive network in the shipboard power amplifier. This network was redesigned and rebuilt. The November sea trials verified this fix. Acoustic signaling ranges of 8000 yards were obtained. During November and December twenty-five days were spent at sea with the navigation system. Only minor difficulties were encountered. It was demonstrated that the system could in fact provide the information to track the submersible and its support ship. A programmable desk top calculator automatically calculated the positions of R/V LULU and the DSRV ALVIN.

(b) Handling and Transfer at Sea

The 24' Coast Guard boat on which aircraft landing gear has been mounted athwartships was used in a variety of maneuvers and sea states. In all cases the shock on making contact with ship or pier is considerably reduced. A combination bumper/transfer vehicle was made from a large tire of the type used in earth movers or heavy ordnance transfer vehicles. This was quite successfully used by a local Coast Guard ship in servicing buoys in the area, which has always been a difficult job from a small boat in rough weather.

(c) Bottom Reconnaissance and Detailed Site Survey

The suite of instruments available, (FM sonar, echo-sounder, calibrated photography, submersible sub-bottom profiler, nuclear densiometer/penetrometer, small rock drill, pry bars), and the mother-ship site survey system were used in several cruises along the East Coast. The limited payload of ALVIN (to be changed with the titanium hull) means that the full suite of instruments cannot be taken on any single dive. The experience gained on each dive resulted in some changes to equipment and a better 'know-how' in their use.

(d) Near Bottom Magnetics Studies Using a Deep Submersible

The proton procession magnetometer was mounted in a buoyant fish and towed from ALVIN on a series of dives. A random noise level of less than two gammas was observed. With the present steel hull heading effects determined by reciprocal courses were less than 10 gammas. Some minor handling problems were encountered, but it has been seen that scientific measurements of magnetics can be made from ALVIN

(e) Near Bottom Gravity Studies from a Deep Submersible

The field tests of the Vibrating String Accelerometer with gimball suspension as a gravimeter in ALVIN showed that acceptable quality measurements could only be made when ALVIN was not under power; (sitting, descending). Accelerations of ALVIN when underway are too large for the above systems. After determining this in field tests investigations were made into small stable platform availability for possible use in ALVIN.

(f) A Self-Contained Deep Sea Rock Drill

The design and construction of the first assembly of the drill were completed, the drill was tested on land and water by drilling in granite rock without attachment to ALVIN. The drill was used from ALVIN in the Bahamas, and while the operation of the drill as a drill was satisfactory, the handling and retrieving mechanics were not, from a time and safety viewpoint. Steps are being taken to correct these features.

(g) Development of Equipment for Use in Deep Ocean Biological Research

A Longhurst Hardy Plankton Recorder System for use from ALVIN to collect plankton very near the bottom, or from discrete layers, was constructed and is in the debugging stage. A sediment trap which collects the rain of sediment before it can interact with the bottom is about two-thirds complete. Two respirometers for measuring oxygen uptake at the bottom by bacteria, biota, and chemical reactions of the bottom were constructed and used from ALVIN.

Box Covers have been constructed and used in deep dives in studies of benthic macrofauna. An elapsed time movie camera has been built to study rates of movement of epibenthic species in invertebrates and demersal fish.

This program has given appreciable impetus to the use of ALVIN by biologists.

Submerged Navigation
and
Submersible Instrumentation

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Submerged Navigation and Submersible Instrumentation

TECHNICAL REPORT

A. Purpose and Background

The objective of the submerged navigation development program is to develop and conduct at-sea evaluations of an acoustic navigation system for submersibles and their support ships. The program began in February 1971. The first six months were spent detailing the basic real time system, procuring the major components, building a prototype of the submersible electronics unit, building a prototype of the support ship system. This report covers the period 1 April 1971 through 31 January 1972 during which the system was debugged and tested at sea.

B. August-September 1971 Sea Trials and Problems

The period 2-14 August 1971 was spent checking the navigation system and preparing the bottom beacon moorings. R/V LULU returned to W.H.O.I. on 15 August. The "basic" navigation system was installed in the bridge of R/V LULU. The ALVIN navigation electronics and hydrophone were installed and shallow water trials with the transponders were completed. The R/V LULU sailed from W.H.O.I. on 24 August (LULU Cruise No. 46) for a combined navigation and biology cruise at the W.H.O.I. Bottom Station #1 (39°46'N, 70°40'W) where the water depth is approximately 1800 meters. The first bottom mooring was launched on 25 August at the Bottom Station. Replies from the transponder were heard during its descent and then no replies were heard after it reached the bottom. After rechecking the LULU receiving equipment the bottom moored transponder was acoustically commanded to release its anchor. Intermittent transponder replies were heard during the ascent. The transponder and mooring were successfully recovered. A second transponder was then launched. This unit gave better results but the transponder replies were no longer heard when LULU moved a short distance from the launch point. ALVIN made a biology dive on 25 August (Dive #346) with the ALVIN navigation subsystem in the automatic mode. The ALVIN slant range signal at 15 kHz was received intermittently at short range and not at all at normal operating ranges. The ALVIN dive on 26 August was cancelled due to high winds and rough seas. The second bottom transponder was acoustically commanded to surface on 27 August and was successfully recovered. LULU departed the operations area immediately after the recovery of the transponder due to the approach of hurricane DORIA. LULU arrived at W.H.O.I. on 28 August after five days at sea.

An ALVIN test dive was conducted in Woods Hole Harbor on 31 August to check the ALVIN-installed 15 kHz navigation transponder. It was found that operating certain ALVIN equipment caused false triggering of the ALVIN transponder.

To learn more about the various acoustic signaling problems the system was taken to sea again on the next LULU/ALVIN geology cruise to the Gulf of Maine. The R/V LULU departed W.H.O I. on 2 September for an

eight day cruise (R/V LULU Cruise No.47). During the cruise transponders were launched and successfully recovered four times. It was found that the transponders were slightly off their specified frequencies. This was compensated for by adjusting the respective narrow band filters in the LULU receiving equipment. The receiving sensitivity of the Model 205 receiving equipment. The receiving sensitivity of the Model 205 receiver was measured and found to be satisfactory. The system performed fairly well except that the operating range was still limited. The 15 kHz channel remained the poorest. Various equipment operating in ALVIN continued to cause interference. Relatively little effort was expended in automatic data recording due to the acoustic problems encountered.

C. Receiver Sensitivity Problem and Solution

Following the cruise an extensive set of tests were scheduled to measure various system parameters. These included bench tests and shallow water tests conducted from the W.H.O.I. dock. The transponders were returned to the manufacturer who modified them for better frequency stability and measurement of the power outputs. The receiving sensitivity of the Model 205 receiver was re-measured and found satisfactory. When the LULU transducer was coupled to the Model 205 receiver via the Model 200 power amplifier it was found there was a significant loss of receiving sensitivity especially at the higher frequencies. The standard AMF system operates over a range of 9.0 to 11.0 kHz. To meet the submersible requirements, specifically to minimize use of the UQC frequency band, 8.5 to 11.0 kHz, the navigation system used frequencies of 7.0, 8.1, 12.9, 13.6, 14.3 and 15.0 kHz. It was found that the major cause of low receiver sensitivity of the Model 205 receiver was due to the transmit/receive circuits in the AMF Model 200 Power Amplifier. After consultation with the manufacturer, the transmit/receive circuits were redesigned and rebuilt. Also to avoid the roll-off characteristics of the LULU installed transducer, the 15.0 kHz frequency was changed to 12.0 kHz. Additional work performed prior to the scheduled November cruise included: procurement of flashing lights for the transponder mooring to assist in recovery, programming of the data processing equipments, and addition of the master clock and precision pressure sensor to the ALVIN subsystem.

D. November/December 1971 Sea Trials

Late in October 1971, the ARPA navigation system was transported to West Palm Beach, Florida, for installation on LULU and ALVIN. The R/V LULU sailed for TOTO on 3 November 1971. During this cruise (LULU Cruise No. 48, Leg IV-A) work continued to prepare for the navigation experiments scheduled to start on 11 November. The R/V LULU docked in Nassau on 9 November. The ARPA Geology and Biology Science party joined LULU in Nassau. R/V LULU sailed from Nassau at 0600 hours on 12 November for a combined ARPA navigation, biology and geology sea trial cruise (LULU Cruise No. 48, Leg 4-B). The navigation transponders were set southwest of New Providence Island. After finding and correcting a minor ground loop noise problem it was encouraging to find that the "receiver sensitivity" problem had indeed been corrected and that LULU could interrogate and receive answers from the bottom moored transponders at slant ranges of up to 8000 yards. During

this cruise ALVIN made seven dives, two were made with an ALVIN navigation equipment operator and during five dives the ALVIN installed navigation equipment was operated in the unattended automatic mode. At night several survey exercises were conducted. The successful cruise was concluded when LULU docked in Nassau on 19 November.

LULU departed Nassau on 24 November to conduct Leg IV-C of LULU Cruise No. 48. The work scheduled for the cruise included tests of the following ARPA developed equipments: rock drill, LHPR sampling system, submersible magnetics system and the submersible gravity system. The submersible navigation system supported all but the rock drill dives. During dive No. 381 the submersible precision pressure depth subsystem was tested. During this test it was found that operating various submersible equipment caused extra counts to be recorded by the frequency counter that measures the output of the pressure sensor. During dive No. 386 the navigation system was used to provide a real time readout of the position of ALVIN during a submerged magnetometer experiment. During the cruise minor difficulties were experienced when the R/V LULU precision clock jumped in one second steps when the LULU installed single side band radio (installed adjacent to the clock) transmitted.

The cruise ended on 3 December when the R/V LULU docked in Nassau. The R/V LULU returned to Woods Hole on 17 December, after which the navigation system was off-loaded and returned to the laboratory.

E. December 1972 - January 1972

During this period the results of the at-sea testing were reviewed and plans for various modifications and improvements of the submerged navigation system were formulated.

Handling and Transfer at Sea

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Handling and Transfer at Sea

1. Technical Problem

The present limited ability to handle, launch or transfer heavy equipment, work boats, and submersibles at sea seriously interferes with the efficiency of many oceanographic and military operations. Even more serious, it has discouraged consideration of concepts and methods for greater tactical use of deep submersibles, specialized work boats and large instruments.

Specific examples are the rarity of pre-scheduled transfers at sea, the occasional difficulty of even getting liberty parties ashore, and the serious sea state limitations when using small submersibles.

2. General Methodology

Several aspects of what has and has not been done in handling leads this investigator to be optimistic that major improvements may be possible along several lines.

The success and wide-spread adoption of resilient energy absorbing approach techniques used by aircraft landing on Navy carriers has shown (Figure 1) that one exceedingly difficult sea going approach problem has been solved by using an appropriate combination of wheels, springs, and energy absorbers with each of the key components and techniques based on rather elementary design concepts. The same concepts and practices have been even more widely applied and hence more generally understood on the wheels and springs of land vehicles.

The first essential part of this investigation is a series of elementary and rather crude experiments in local waters to see if the difficulty and danger usually inherent in contact between a work boat and a ship in a seaway can be significantly reduced. The second part of the investigation is to compute and estimate more refined design criteria for the approach and contact problem in the light of previous experience. The third part of the investigation is to try and apply these principles to a few actual cases where meaningful field results can be obtained.

3. Technical Results

(a) Longitudinal Boat-like Craft

The 24' Coast Guard work boat (Figure 2) with the resilient approach gear units continued to be used locally. Fortunately at the time of the ARPA Visiting Committee it was possible to demonstrate some of the characteristics of the system to members of the committee.

As the tests continued utilizing Coast Guard and Institution ships, the investigators became impressed by the fact that one could lay alongside a ship on an exposed windward side with a new degree of safety and relaxation. However, to exploit this charac-

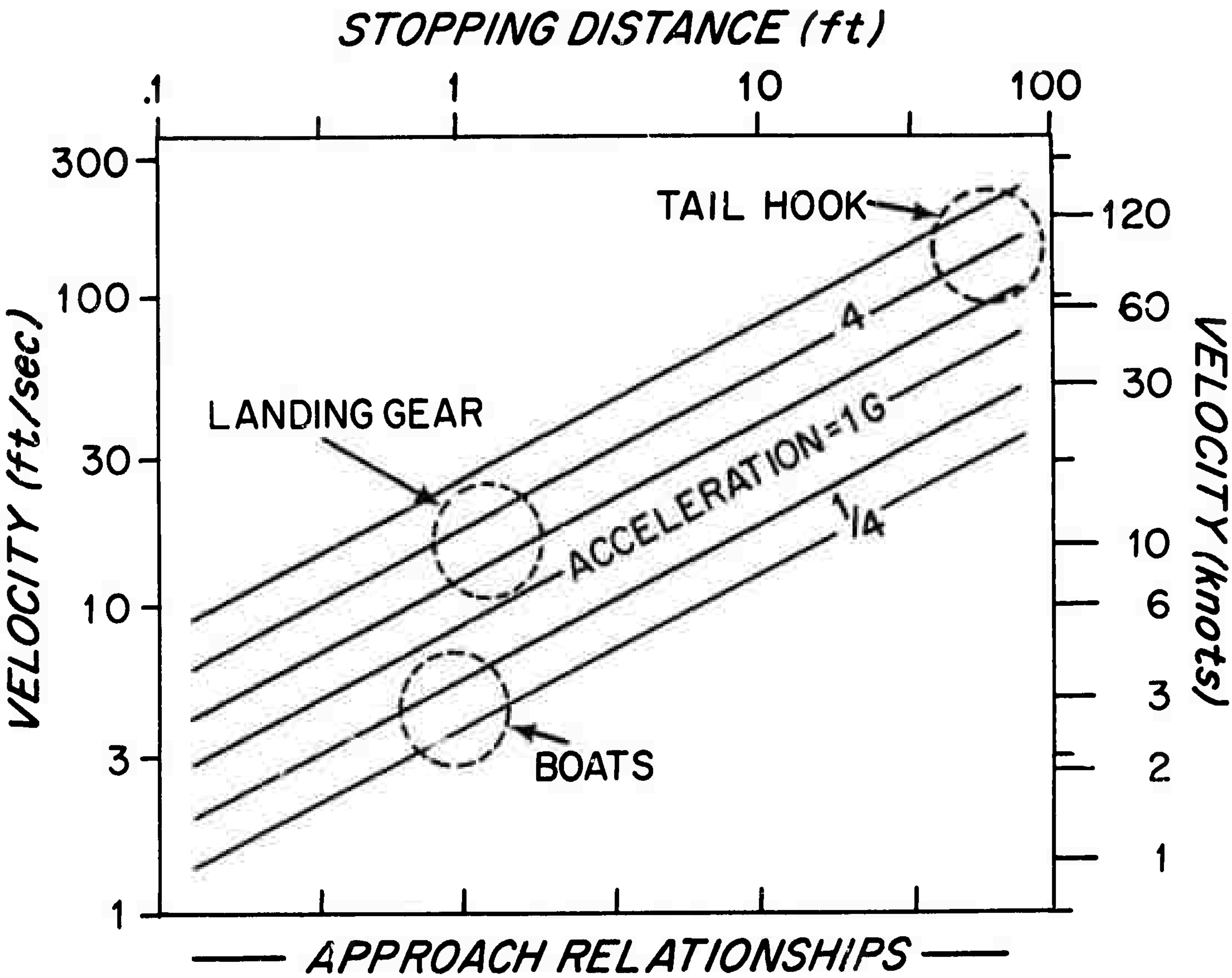

Figure 1. Mechanical relationships involved in the design of approach and contact systems for aircraft, automobiles, and boats.

Figure 2. Resiliant approach system with full castering wheels to investigate mechanical and physiological response to horizontal and vertical motion.

teristic further it would be essential to get a considerably more capable small boat. In particular it would need (1) at least 12 knots speed to adequately maneuver alongside a slowly moving ship; and (2) a boat sufficiently covered to minimize the change of being swamped by a large wave reflecting off the side of the ship. Considerable time has been spent trying to find a boat with these characteristics to which the energy absorbing approach gear could easily be added. An attempt has also been made to try and find a boat that was well adapted to serve as a useful work boat. To date no such craft has been found but it is hoped that a Coast Guard plastic 30' boat or a Navy personnel boat can be found.

A visit was made to the Davis-Monthan Reserve Airport in Tucson to examine the landing gear assemblies of reserve bombers on the possibility that an experimental rig might be tried on a 100 to 150 foot ship such as a USCG patrol boat or a Navy PGM.

Not enough is known about the motion forces and damping on a boat in a seaway to know if the shock absorber action of the aircraft wheel assembly does very much good. Hence it is planned to make some comparison trials placing greater emphasis on spring action and less on the shock absorber action. The reason being to see if the gear can be further simplified without loss of effectiveness.

(b) Round Buoy-like Craft

Initially work was done on the round resilient buoy as a buoy for the Coast Guard under a small Coast Guard contract. However, its use as in Figure 3, as a utilitarian fender and transfer vehicle looked promising and two of the large tires were purchased under this contract. It is considered as a manable buoy-fender.

An unexpected but interesting application for one of these tire-rafts occurred recently in Woods Hole as a result of a bridge being temporarily out of operation. The manable fender-buoy was used for transporting people across the water.

Some of the logic and inherent advantages of a circularly symmetrical resilient transfer vehicle over a conventional skiff or boat were self demonstrated by several hundred scientists and residents of Woods Hole. This was a fortunate circumstance because many oceanographers became sufficiently involved to see that some of the normal problems with skiffs could be by-passed. Figure 4 from a local paper illustrates the usage.

A specific use for which this tire-float-fender arrangement is being considered is an accomodation ladder from a dock or ship as shown in Figure 5. The resilient tire would serve as the float, fender and lower platform of a gangway ladder. The ladder would be hinged and pivoted at the top and bottom so that the bottom could rise and fall with the boats as they came alongside. The large round tire should eliminate the need for the small boats to use fenders. An alongside boat is shown in Figure 3.

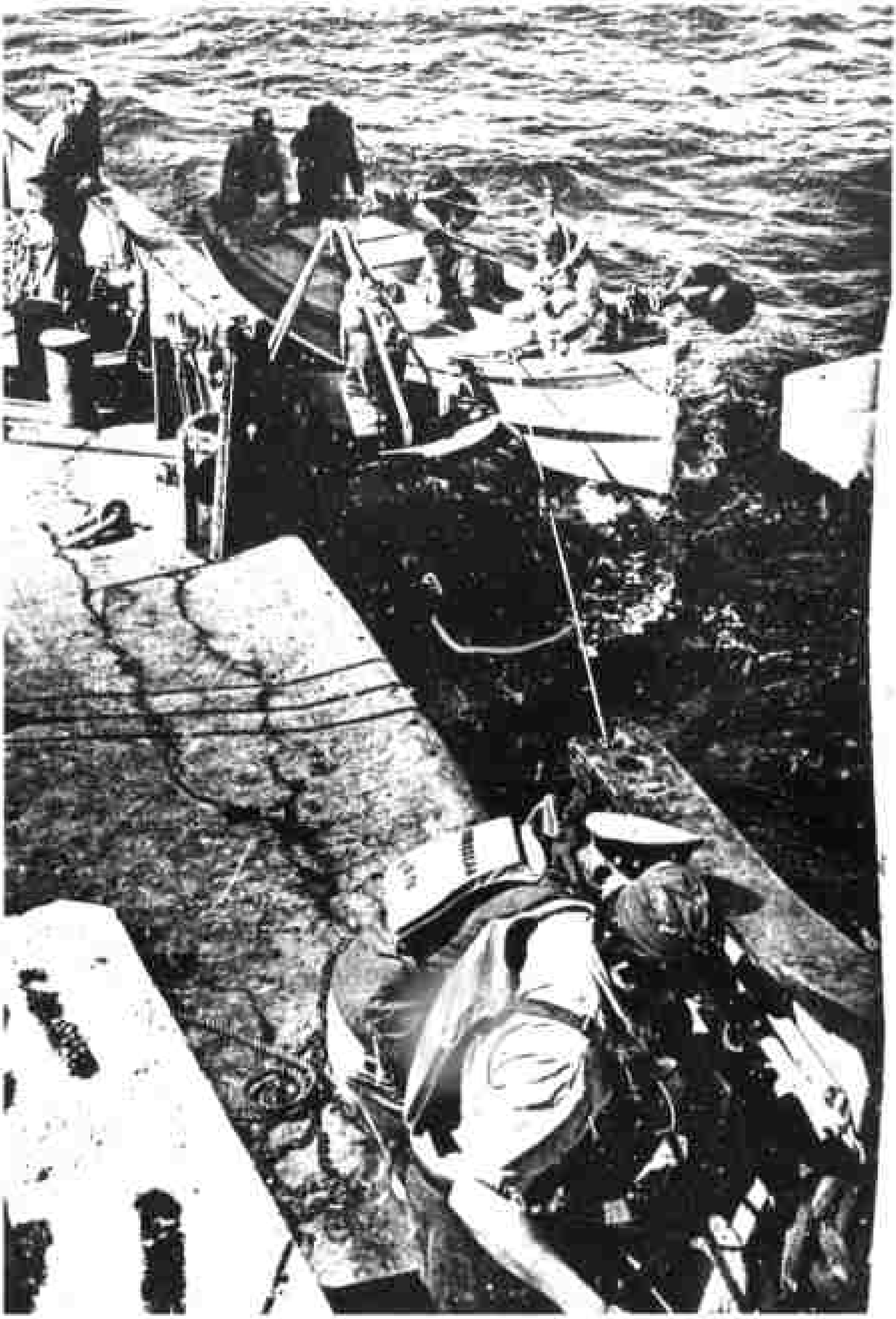

Figure 3. Mannable buoy used as a fender and transfer platform between ship and small boat.

Figure 4. An unusual secondary use for the mannable buoy. During bridge repairs townspeople utilized the buoy as a hand-operated "Norwegian Steam" ferry instead of using more awkward skiffs.

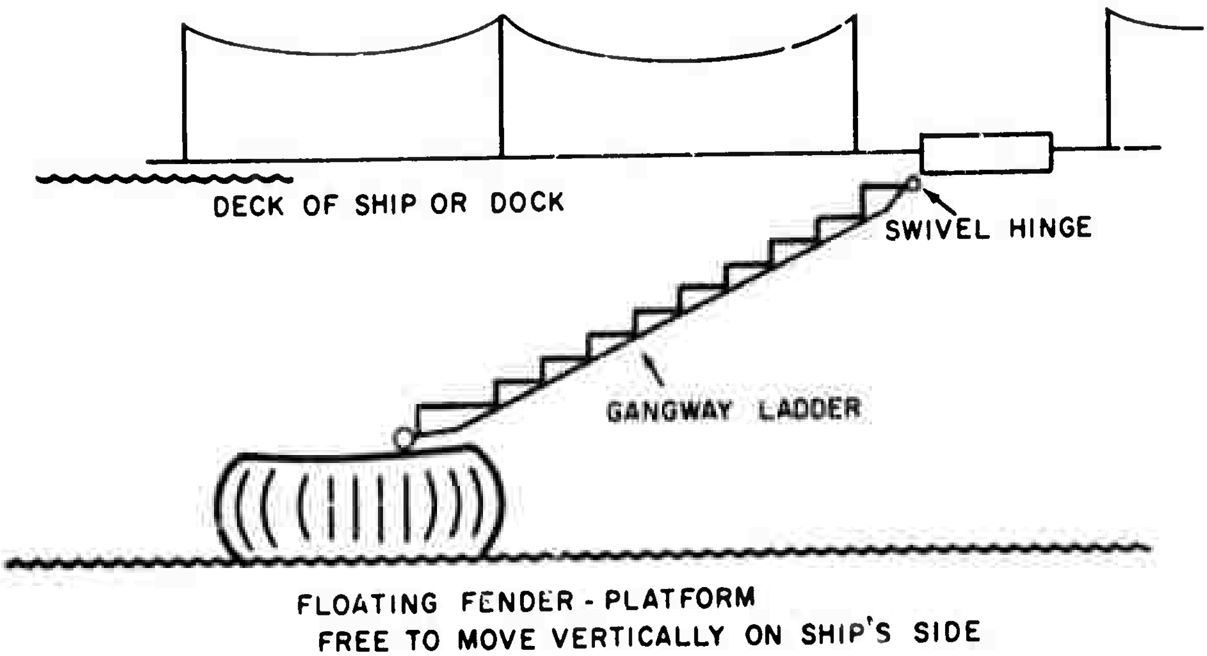

Figure 5. Floating over-the-side gangway, fender and landing platform free to move vertically along ship's side.

4. DOD Implications

The general need for an improved capability in transfer and handling of people and equipment from ships in heavy weather is apparent and might be divided into two classes of problems.

(a) Those which are now done but where improvement is desired, to include: (1) amphibious operations; (2) liberty parties; (3) small submersibles and work boats; and (4) some heavy salvage equipment.

(b) Those projects which have essentially not been undertaken or adapted because it was feared that handling problems could not be solved. Advantages from these may only be potential as they are unproven:

(1) handling large acoustic arrays,

(2) handling rather delicate hydrofoil craft from ships,

(3) having deep submersibles on key warships or salvage ships.

Bottom Reconnaissance and a Detailed Site Survey
by Research Submersible

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Bottom Reconnaissance and Detailed Site Survey by Research Submersibles

Introduction

The geological bottom reconnaissance program is aimed at developing a series of instrument systems for the DSRV ALVIN and its support ship LULU which will significantly improve the ability of deep submersibles to carry out meaningful geological investigations. Deep submersibles are capable of assisting geologists in three major areas: the investigation of dynamic processes and structural features through detailed surveys, the collection and description of important bedrock exposures, and the placement of large bottom mounted instruments for short and long term measurements.

Major Accomplishments During the First Contract Year, (February 1, 1971 to January 31, 1972)

1. Calibrated Photography

An engineering study was initiated and completed in the first contract year which was aimed at calibrating the port and starboard portholes of ALVIN. Knowing the optical properties of the plexiglass portholes, the characteristics of a standard NIKON camera and 24 mm lens, and the flight behavior of ALVIN it was possible to develop a computer program which when given the altitude at which the photo was taken can provide a calibrated grid that can be superimposed on the various photographs collected. This study was conducted as a first step towards providing the geologist with quantitative information about various bottom environments. The capability, however, has two major limitations: (1) the calibration calculations are based on the assumption of a bottom flat that parallels the submersible and (2) the system is good only for hand held photographs taken through the portholes and not for the external EG & G cameras which take the majority of photographs during any one dive. The next logical step in this program would be to design and build a laser ranging unit for the external camera system which could be used in extremely rough terrain. This unit would project a series of small light reference spots on the area photographed which would be used to orient and calibrate the photographic plane in space and time.

2. Submersible Sub-Bottom Profiler

A 5 kHz submersible sub-bottom profiler was acquired on loan from the U. S. Naval Oceanographic Office. A detailed description on this unit is given in the first semi-annual report and will not be repeated here. Considerable time was spent in the laboratory overhauling the unit and placing it back in operational condition. The unit was then mounted on ALVIN and underwent preliminary testing during harbor trials. During these trials the system worked intermittently, a problem which was traced to loose wiring. The five kHz profiler was then tested at sea during a dive series in the Straits of Florida. Wiring problems continued to reoccur but when the system operated, it resulted in the collection of unique and valuable information about the subsurface structure of sediments in the floor of canyons; information unattainable using conventional surface techniques.

The specific unit used in this evaluation had two basic limitations: (1) the system - including transducer and recorder - weights over 110 lbs. in water which uses up a substantial fraction of the available science payload. Thus, the unit was not taken on all dives since it precluded the use of other instruments, (2) the instrument has only one operating frequency, that being 5 kHz. A more useful system should permit the geologist to use a variety of frequencies depending upon the physical characteristics of the bottom sediments.

3. Nuclear Densiometer/Penetrometer

In an attempt to expand the geological capabilities of the submersible, a joint soil engineering effort was initiated between Lehigh University and W.H.O.I. The purpose of this program was to encourage engineers at Lehigh to design, construct, and test a nuclear densiometer/penetrometer for use from ALVIN. As a result a photo-type unit was built which weighed approximately 400 lbs. in air and 300 lbs. in water. A detailed description of this unit is contained in the first semi-annual report. In the second quarter of the contract year, the nuclear densiometer/penetrometer was used from ALVIN to measure in situ the mass physical properties of sediment bodies in the Gulf of Maine. The data collected was subsequently evaluated and reported at the 1972 Offshore Technology Conference. The report clearly shows that a small submersible is capable of developing the reaction force needed to penetrate a probe greater than one (1) meter in soft sediments and obtain useful results.

4. Shipborne Site Survey System

Most geological missions involving a submersible must be supplemented by additional information in the form of precision echo-sounding, detailed seismic profiling, and refractions information which can be collected before specific dives are conducted. To meet that need a shipborne site survey system was placed aboard the R/V LULU. The system consisted of a continuous seismic profiling (csp.) system, a 12 kHz echo-sounder and recorder, a sonobuoy receiver and sonobuoys, a 3.5 kHz transducer and an Omega navigation unit. This survey system was placed aboard LULU as supporting instrumentation and not as an instrument development program in itself. For that reason the major components were borrowed from other projects and only minor support from A.R.P.A. was required.

5. Detailed Sampling Systems

One of the most important geologic missions for a small submersible is to obtain representative samples from bedrock exposures. To insure the optimum use of the vehicle the sampling system should be small, lightweight, have a rapid cycling capability, be operational at neutral buoyancy, not require time consuming ballasting and trimming, be easy to operate, be functional in rough terrain having vertical exposures, and not involve the use of the mechanical arm except to pick up the samples. As a first step the present sampling techniques used by ALVIN were evaluated during several dives in varying bottom terrains. A small drill developed under a previous instrumentation program with the Naval Oceanographic Office was evaluated during a series of dives on igneous exposures in the Gulf of Maine. The

drill required too much time to use, required lengthy periods of ballasting and trimming to attain the necessary vehicle attitude, had no tactile feedback which led to frequent jamming, and if successful obtained samples which were too small for a variety of experiments. The large drill developed under A.R.P.A. sponsorship was also used in the Tongue of The Ocean. This drill has great potential in the future for a limited number of specific studies. It is not, however, a general purpose sampling device as it consumes most of the submersible's science payload, requires a level and near horizontal bottom, can only be used on a few outcrops per dive, and requires that the mechanical arm be removed for the dive. At present the best sampling technique from ALVIN is the use of the mechanical arm and pry bars to remove rock samples along joints. This technique is unreliable as most of the samples collected consist of highly weathered rocks. In addition this technique is too time consuming. A study is presently underway to design a new sampling system for ALVIN for initiation in the second contract year.

Near Bottom Magnetics Studies
Using A Deep Submersible

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Near Bottom Magnetics Studies

Problem

Installation and field testing of the towed proton magnetometer system described in the previous technical report (W.H.O.I. Technical Report 72-53) was the principle technical objective of work conducted in this reporting period. The effects of vehicle heading and ambient magnetic noise level during normal ALVIN operation are considered the principal measurement to assess the suitability of the system for scientific observations. The overall feasibility of a towed sensor aboard a submersible vehicle is to be evaluated by the ALVIN pilots.

Methods

A. External Installations

A standard Varian observatory type sensor (Model #49-843) modified for operation at pressures up to 8000 psi was mounted in a syntactic foam tow fish (Figure 1). A tow cable consisting of 15 meters of braided hollow polyurethane line connected the fish to ALVIN. A shielded electrical cable made up of two twisted #14 gauge conductors in an oil-filled jacket (Belden 8428) was threaded through the tow cable. An electrically triggered guillotine-type safety disconnect system was located at the tow point on ALVIN conning tower.

B. Internal Installations

A Varian 4937A airborne magnetometer electronic console modified for DC operation was mounted in the normal scientific instrument rack aft of the pilot's stat on. Originally it was planned to connect the unit directly to the ALVIN's 28 volt power supply; however it was found that the Varian electronics system uses a chassis ground circuit configuration. Since this configuration is not feasible aboard submersibles because of electrolysis problems and simple isolation of the chassis is not considered a safe operation procedure, an alternative power connection was devised. The ALVIN's inverters were used to provide 60 cycle AC power which was then converted back to 28 volt DC with the appropriate grounding configuration. While grossly inefficient from a power consumption viewpoint this set-up was employed as an interim step simply for the purpose of testing the overall feasibility of the towed sensor system.

Results

Several test dives were made in the Tongue of the Ocean near the New Providence Island site off Nassau in various water depths during the period 23 November to 2 December 1971. The results of these dives are summarized below:

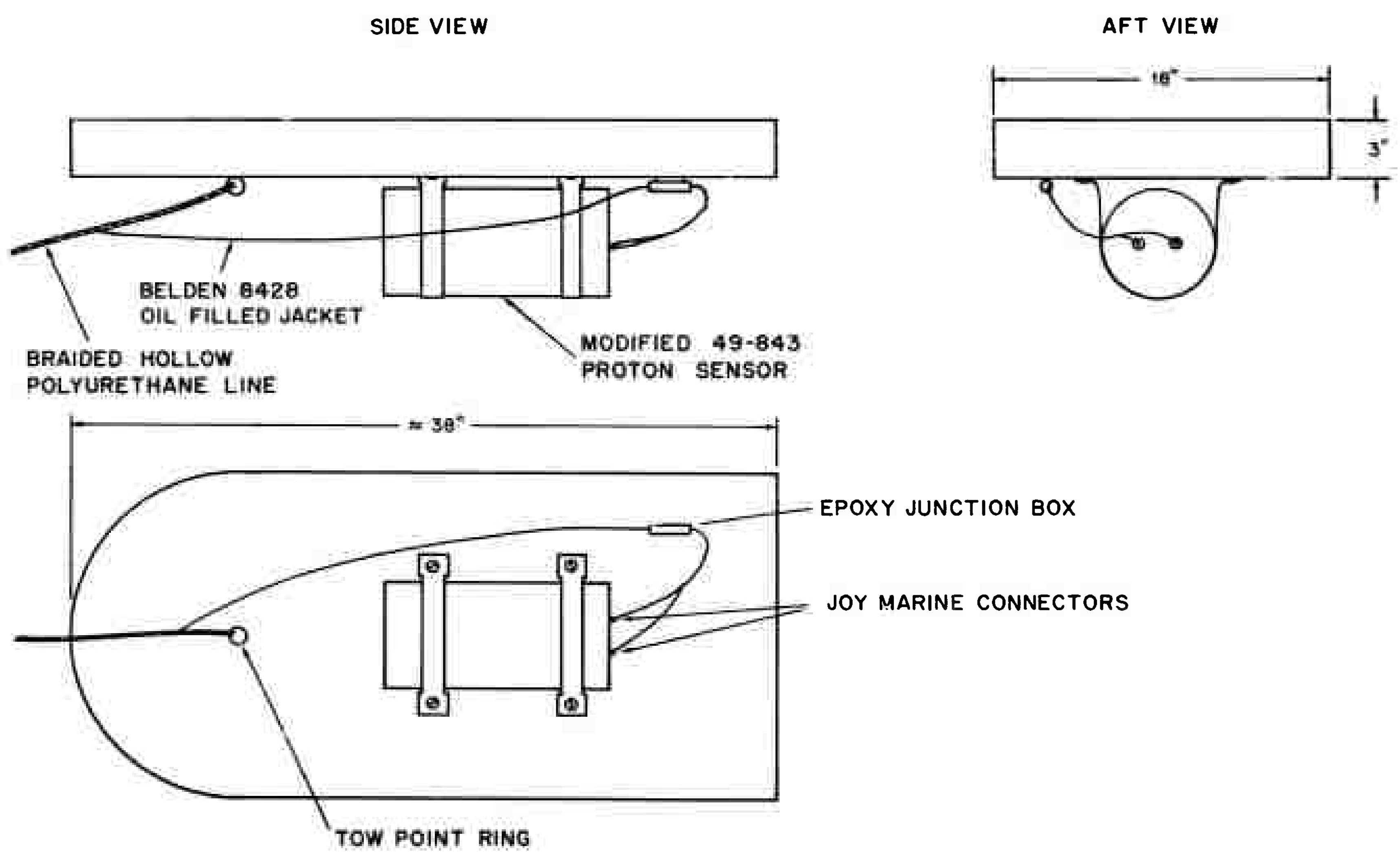

Figure 1. Sketch of proto-type ALVIN magnetometer Tow Fish.

(a) Noise level: Careful inspection of the strip chart records shown in Figure 2 reveals that the random noise level of the system in ALVIN's normal operating configuration is less than ±2 gammas. The large spikes on the records result from voice transmissions on the QXC sonar system. This noise level is acceptable for most scientific observations however efforts will be made to reduce the noise, particularly the sonar interference.

(b) Heading effects: To test the effects of ALVIN's steel hull on the magnetometer observation several reciprocal heading tracks were run at constant depth over the same terrain. The total water depth was approximately 5000' through each run. Navigation was provided by the ALVIN's bottom transponder system. The results of these tests are shown in Figure 2. Overall it appears that the heading effects are less than 10 gammas maximum as predicated for our theoretical calculations. The maximum effect is seen on the reciprocal north-south tracks between 1510 and 1642Z. Note the DC level of the north runs is about 6-8 gammas higher than in the south track. On east-west runs the heading effect must be less than 2-3 gammas as evidenced by the nearly identical traces recorded between 1500 and 1510Z. It is also important to point out the effect of ALVIN's stopping in the magnetic records. Note that the observed field invariably increases about 8 gammas when ALVIN is stopped compared to when underway. This is explained again by the effects of the steel hull In the normal towing mode the sensor trails directly behind ALVIN about 12-15 meters and is nearly horizontal. Upon stopping the sensor floats toward the steel hull and eventually hovers directly above it. This is predictable in that an increase in magnetic field intensity directly above and along the axis of a dipole source in the Northern Hemisphere is to be expected as compared to the field intensity normal to the axis.

(c) Operation feasibility: It was found in general that the towed sensor did not interfere with underway operations. However, it was observed that certain of the launching and recovery aspects of the towed system should be changed in order to improve the efficiency from a time and safety aspect. These include the following:

(1) The ascent rate of the syntactic foam fish is somewhat slower than ALVIN's maximum ascent rate. Accordingly, ALVIN must slow in order not to become entangled with the magnetometer tow cable. This slow fish ascent rate is attributed to the large cross-sectional area of the fish.

(2) The buoyancy of the tow cable is not sufficient to float the inner electrical cable. This results in the fish floating toward the ALVIN when on the surface. This makes for a more difficult approach of the divers' work boat for disconnecting the cable/fish from ALVIN.

(3) The guillotine safety disconnect system is not adequate for routine scientific operations. It requires considerable time and skill to arm and disarm the device properly

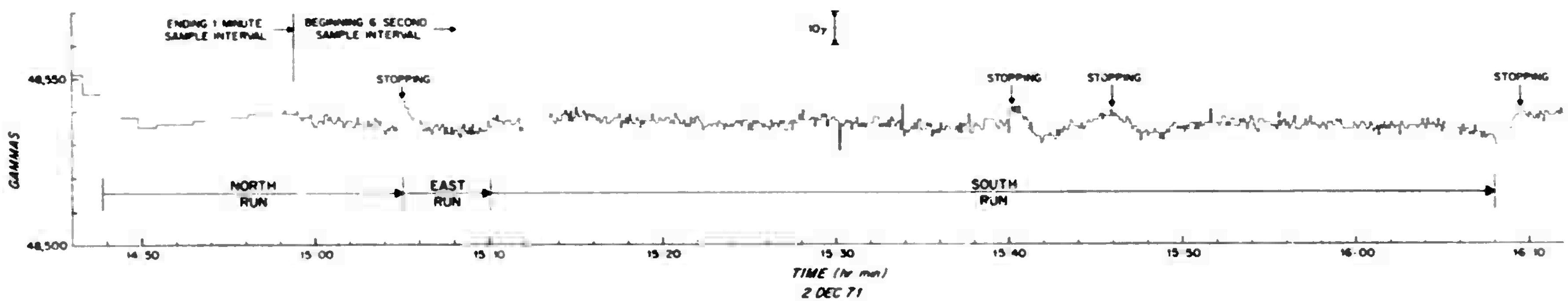

Figure 2. Total intensity magnetic profile using proto-type ALVIN towed magnetometer system.

for each dive. It is also suspected that it may not completely sever the cable because the polyurethane is not always cleanly sheared by the guillotine jaws in bench tests.

(4) The interim isolation type DC power supply configures for the Tongue of the Ocean test dives is not adequate for normal operation. A direct connection to the ALVIN 28 volt supply must be developed.

(5) The space/weight configuration of the present on-board electronic console is also too large when considered in terms of all the scientific systems which must accompany the magnetometer during scientific dives (digital recorders, navigation system, telemetering system, etc.). A much smaller and lighter unit is clearly required.

Summary

The towed magnetometer system using the interim Varian 4937A magnetometer was found to be totally useful for scientific observation aboard ALVIN. The normal ambient noise level of the system is less than ± 2 gammas. Maneuvering and heading effects are less than 10 gammas. The latter effects can be eliminated by a small increase in tow cable length.

While the operational feasibility of the system was also judged to be very good, several improvements must be made, namely: the tow fish/cable must be made more buoyant and streamlined so as to ascend faster than ALVIN's maximum ascent rate; the magnetometer electronic circuitry must be redesigned so as not to use a chassis ground configuration in order to allow direct connecting to ALVIN's 28 volt power supply. A new type safety cable disconnect system is required for routine use of the towed sensor system.

Near Bottom Gravity Studies
from a Deep Submersible

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Near Bottom Gravity Studies from a Deep Submersible

The preliminary ALVIN dive tests (described below) conducted in November 1971 showed the acceleration of ALVIN to be higher than anticipated. Investigations of various types of stable platforms, for this use, are now being conducted. It now appears quite likely that a wise course of action will be to obtain a stable platform which is, as well, a miniature inertial navigation system.

Field tests of the A.R.P.A. gravimetry system were conducted during late November 1971 in the Tongue of the Ocean, Bahamas. Equipment for the field test included the VSA oven and read-out, gimballed suspension for the VSA oven and read-out, gimballed suspension for the VSA sensor-oven, power supply, data system, and a two channel strip chart recorder. Personnel included T. C. Aldrich and B. P. Luyendyk of this project, and Dr. R. Steer of Frequency Devices, the company who manufactured the VSA read-out, who acted as a consultant at no charge to this project.

Before field operations considerable problems were evident with the data multiplexer system. Recording was occurring at uneven intervals. This problem was eventually solved with the aid of company engineers. However, we were still left with a formating problem which resulted in too short record lengths.

On 26 November 1971 we tested the system in ALVIN at a location a few miles west of Clifton Pier in 600 to 1300 meters of water. Equipment included the VSA sensor, oven and read-out, TOPAZ power supply, and strip chart recorder. Digital recording was not attempted because we were interested in seeing results in real time and analogue and digital recording cannot be done simultaneously because of power-space limitations. T. C. Aldrich operated the system during the dive.

The mission profile included diving to about 300 m depth and running in a southerly direction on constant course for about one hour. This course was selected so as to minimize the Eötvös correction and minimize topographic effects since this course was also along the strike of the topography. In this manner we hoped to obtain acceleration information for the submarine alone. The track of ALVIN was determined by transponder navigation in real time so that the shipboard control had a good idea of its course and speed during the dive.

During controlled descent, with no forward power applied, the system operated well and no noise greater than 10 mgal was evident. Once underway on course the noise level increased significantly. The disturbing factor appeared to be minor course adjustments. Adjusting the ALVIN rudder shocked the gimbal system and caused the sensor to swing with a coneing motion. This produced a signal increase on the order of 50 mgal which took approximately one minute to damp out. Other noise patterns could not be distinguished because of the overwhelming effect of the unstable suspension. Because of this problem, other tests were not attempted.

In our proposal to A.R.P.A. for 1972 we indicated that we had come to the

conclusion that the originally proposed damped gimbal gravity meter suspension would not prove serviceable for routine operational conditions. The gimballed system once set in motion will continue to swing, unless damped, but damping will tend to make the system tilt if the point of suspension is displaced. The translation of a gimballed pendulum when the submersible accelerates leads to an erroneous gravity output requiring a correction (Browne Correction) for which information is not available. Subsequent to our original proposal we learned that the axes of rotation of the damped gimbal cannot be consistently located near the center of rotation is variable and changes with drag and mass distribution. Also we came to learn that the motion of ALVIN in level flight was not as stable as we had originally thought it would be. The gravity test dive in November 1971 confirmed these suspicions and demonstrated that attempts to utilize a gimbal suspension for in-flight gravity observations in a small submersible are not practical.

We have come to the conclusion that rather than develop a system which would yield useful gravity information only during periods of time when the submersible "acceleration noise" is very slight, or to attempt an involved development of an optimum gimbal suspension system with associated instrumentation for determining a Browne correction, that the only prudent course would be to proceed in the development of a small accurate stable platform with low power requirements. Such a platform appears to be an achievable engineering goal. It would make gravity measurements of usable quality possible throughout a dive of the submersible. With a stable platform, the navigation system would become the limiting factor in the gravity measurement accuracy, rather than the gravity instrumentation itself. In this way, submersible gravity measurements might become more routine rather than their continuing to place very stringent limitations upon the submersible's maneuvering while surveying the seafloor. Thus the principal thrust in instrumentation will be the development of a miniaturized stable gravity sensor platform that will adhere to stringent space, power, and vertical accuracy requirements. Typical similar platforms already in existence are either too large, or considerably less accurate than is required for good gravity measurement. Once developed, such a platform would have a wide range of usefulness not only in submersibles, but surface ships and aircraft as well. The small size and low power requirements would also greatly increase the portability of accurate dynamic gravity meters to any location on earth.

During this contract year (1972) we have been investigating three alternate approaches for providing a stabilized platform. One, is to develop a two-degree of freedom slave platform stabilized by a three-degree of freedom inertial navigation system that provides sufficiently accurate reference signals, and the third approach has been to develop an inertial navigation system that can stabilize directly an oven containing the VSA gravity sensor. The first approach would be the least expensive, but would only provide vertical stabilization of the gravity meter. The second approach would require the greatest amount of space and power. In addition, there appear to be only four inertial navigation systems in existence (being built for deep submergence recovery vehicle) that could perhaps meet the accuracy requirements and fit in ALVIN. It is highly unlikely that one of these systems could be used in the gravity program, and even if available, the resulting system would be cumbersome and not as cost effective in the long term as would either of the other two approaches. The third approach presently appears to offer the greatest advancement. A compact gravity/navigation/data acquisition system could be designed utilizing a common

binnacle and digital computer. The portability and performance of such a gravity/navigation/data acquisition system would provide a greatly increased capability to obtain gravity measurements in remote areas as opportunies arise to use conventional and exotic vehicles. Unfortunately, this approach is no doubt the most expensive.

We have had several discussions with each of three groups at the Charles Stark Draper Laboratory of M.I.T. in explorations of the state-of-the-art and the feasibility of developing a portable, low-power, high accuracy, stabilized platform with or without inertial navigation capability. These groups are much interested in the problem, and one or a combination of them, will be making budgetary estimates of the funding requirements for such a development.

A Self Contained Deep Sea Rock Drill

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A Self Contained Deep Sea Rock Drill

Introduction and Background

The initial semi-annual report, covering progress through July 1971, described our preliminary considerations and design decisions, based substantially on the experience of others with similar drills. In the initial design and construction phase, the rock drill system was divided into five subsystems; (1) drive system, (2) power source, (3) drilling system, (4) frame, and (5) ALVIN attachment. As development progressed, two more systems became important; (6) control, and (7) monitoring and data collection systems. All of these systems except (7) were designed, constructed and used in the version of the drill tested during the period October-December 1971. Whereas these tests, including some with ALVIN in shallow water, were generally successful, a number of modifications were indicated. During the second year it is planned to (1) make these and any other modifications that become necessary, (2) conduct extensive tests including deep water tests with ALVIN, and (3) develop the monitoring and data collection system.

Systems Design

A simple schematic diagram of the drill is shown in Figure 1. The present subsystem development can be described as follows:

Drive Subsystem

The prime mover is a standard 36 VDC electric motor rated at 3 kw and 1550 rpm in air. With minor modification this motor is capable of delivering over 4 HP while operating in oil. The motor has been tested to 6000 psig and has been used in all drilling tests to date without difficulty. The oil used in the motor pressure compensating system is MIL-L-6081C, Grade 1010[1]. The drill and pumping systems are coupled to the motor through a chain drive.

Power Source Subsystem

The 36 VDC required for the main motor and oil heaters, and the 24 VDC required for various relays and the main valve actuator, are derived from three high capacity 12 VDC automobile batteries. These series-connected batteries are contained in an oil-filled pressure compensated thermally insulated box. This box also contains the larger electrical components and a central wiring terminal. The oil heaters are used to (1) reduce motor losses by lowering oil viscosity and (2) to increase battery capacity which is highly temperature-dependent.

Drilling Subsystem

The drilling system utilizes a standard diamond set rotary bit of XRT size designation, which bores a 1.155-inch diameter hole and retrieves a .735-inch diameter core. The coring bit, core breaker, core catcher and core barrel are of a type standard to mining exploration industry and

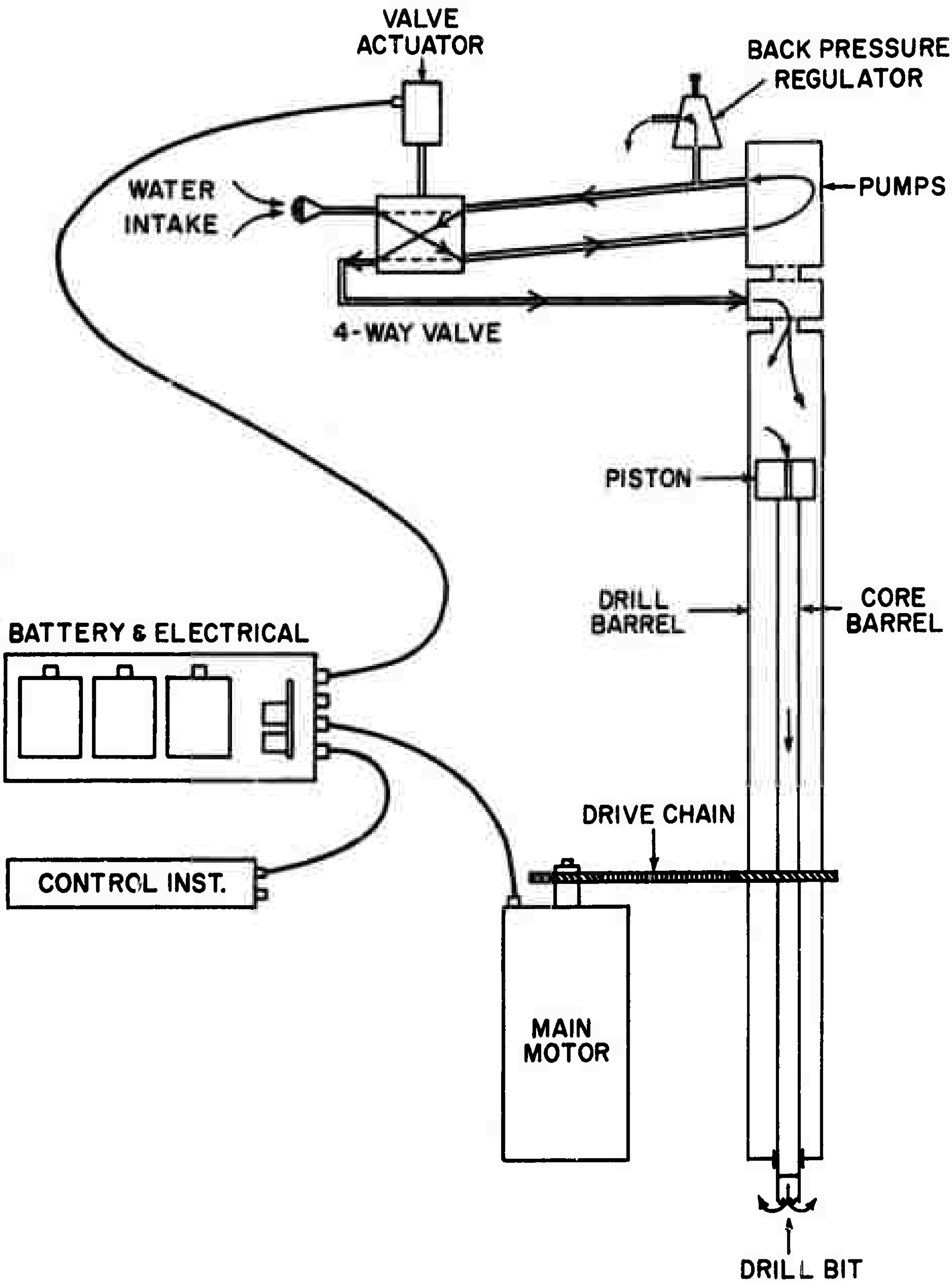

Figure 1. Simplified schematic of drill system.

therefore of proven reliability and are readily available[2]. The upper end of the core barrel is attached to a piston (Figure 1) through which it receives its rotary motion, down load force and drilling fluid. The piston and core barrel telescope from the drill barrel as drilling proceeds. Through a chain drive, the main motor provides the rotary motion of the drill barrel and the power to the pump rotors. These pumps supply sea water pressure (1) for down loading the drill bit; (2) for drilling fluid to wash and cool the bit, and (3) through a valving arrangement, for providing the force required to break the core and retract the core barrel at the termination of drilling. During testing, this system supplied inadequate drilling fluid pressure for drilling certain sediments and is being modified. In addition, this subsystem is designed to be able to handle larger diameter swivel-type double tube barrels with only minor modifications. Of course, with larger bits, drilling rates would be reduced accordingly; however, the swivel feature may improve quality of core recovery.

Frame Subsystem

The frame is constructed of aluminum (6061-T6) channels which are bolted or welded together as desirable. It is designed:

(1) to minimize vibration associated with drilling,

(2) to be sufficiently light weight so as to be compatible with ALVIN's payload,

(3) to provide a platform for effectively mounting all drill components,

(4) to provide a stable base for drilling on an uneven sea floor,

(5) to minimize the moment arm of the drill mass with respect to ALVIN's center of gravity.

The last requirement is important since it is desirable to minimize the amount of ballast trimming necessary to compensate for the drill.

ALVIN Attachment Subsystem

Besides being able to allow ALVIN to detach and recouple to the drill with ease while submerged, the system must be able to:

(1) safely support the air weight of the drill,

(2) allow emergency jettisoning of the drill under almost any conceivable situation,

(3) not interfere with ALVIN's launch and recovery operations,

(4) be attached in such a way that it does not interfere with ALVIN's visual or acoustic sensing systems,

(5) be attached to ALVIN without requiring excessive time, i.e., no more than a few hours.

It was found that the inaccessibility to the major strength members of ALVIN imposed severe limitations upon an effective design.

The initial device proved to be inadequate, but the knowledge acquired in our testing series is believed to be sufficient to redesign a workable sub-system. Some of the problems in our initial attachment system included:

(1) several structural components of the drill and coupling device protruded unnecessarily far from ALVIN and endangered safe launch and recovery operations except in the calmest of seas,

(2) the recoupling step required in a normal operation with this system, proved to be extremely difficult.

The submersible pilot must make the re-attachment. If he cannot clearly see the required contact points and have a reasonably large margin for error, his job is too demanding. Components lying anywhere but directly in front of the ALVIN viewing ports suffer severe vusual distortion. For the most part, our system was unsatisfactory due to the unreasonably high precision maneuvering required of the ALVIN, combined with the visual distortion experienced by the pilot in the coupling procedures.

Control Subsystem

At the heart of the control system is a stable crystal controlled oscillator and count-down chain. COSMOS logic family elements are used to generate the various control signals which in turn operate sets of control relays.

All control functions are either initiated (1) directly by the timing circuit; (2) by some drill status sensing device; or (3) by tactile command from the submersible. The primary control is the timing circuit which initiates the following operations in sequence: (following ALVIN/Drill mechanical decoupling -

Time	Operation
t_0	ALVIN/drill decoupled
t_1	Drilling is initiated
t_2	Drilling stops
t_3	Core barrel retraction begins
t_4	Core barrel retraction stops

Sensing devices can stop drilling prior to time t_2. These devices monitor for (1) high battery current, (2) low battery voltage, or (3) the drill having reached a predetermined depth (this later sensing device is not yet constructed). In addition, at any time after time t_2 ALVIN may command

retraction. A program option of this subsystem allows the submersible to recouple to the drill, relocate it, and then repeat the drilling sequence. However, it is possible to core a total of only two meters.

Monitoring and Data Collection Subsystem

These systems are in their early development stages. The drill status sensing devices developed for control are to be input to an acoustic telemetering pinger and relayed to the ALVIN mother-ship for evaluation. After drilling has ceased, the telemeter inputs can be switched to monitoring and will transmit data from the drilled hole, eg, temperatures. The acoustic telemeter will also allow for easy relocation of the drill by ALVIN.

Testing Series

The first series of tests were conducted in air on the Woods Hole Oceanographic Institution dock in October 1971 (Figure 2). A total of several feet of granite rock were successfully cored on several test runs. Following these, shallow water tests were conducted off the W.H.O.I. docks (Figure 3). Aside from some minor difficulties, the only significant problem observed during these tests was that soft sediment seemed to clog the drill bit. Again granite rocks were successfully cored and all systems were tested except the ALVIN attachment subsystem (due to the inaccessibility of ALVIN).

The results of these tests warranted participation in the testing period scheduled for later November 1971 with ALVIN in the Bahamas. Again the drill performed in a generally satisfactory manner; however, the difficulty in drilling in soft sediment persisted and the lack of hard rock outcrops prevented any core retrieval. Besides drilling during these tests, the drill was successfully jettisoned (as required by ALVIN safety regulations). As previously mentioned, the ALVIN coupling device developed for these tests turned out to be less than adequate. This prevented any deep dives with the drill.

Figures 4, 5, 6 and 7 illustrate the configuration and use of the drill with ALVIN. ALVIN has never before carried a load this heavy; nor one as sophisticated electromechanically; nor one that it had to be able to detach from, and recouple to, during a dive. The lessons learned during this testing period, both by this development team and by the ALVIN crew, showed the feasibility of ALVIN operations with the drill. We believe the modifications currently in progress will come close to making the use of this sort of system possible on a routine basis.

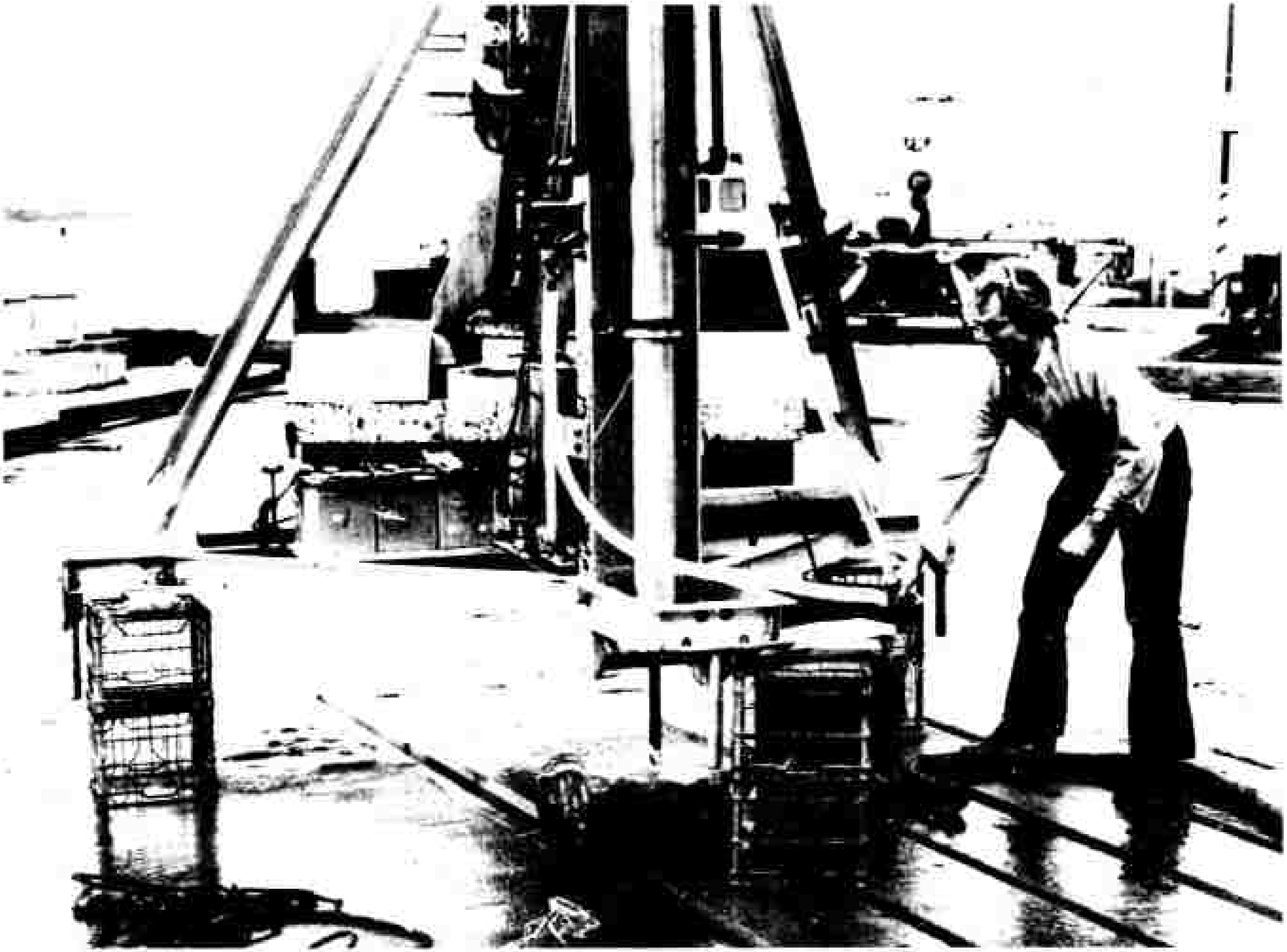

Figure 2. Coring granite rock during initial testing on the W.H.O.I dock (October 1971).

Figure 3. Rock drill being lowered into the water during testing being conducted on the harbor bottom alongside the W.H.O.I. dock (November 1971).

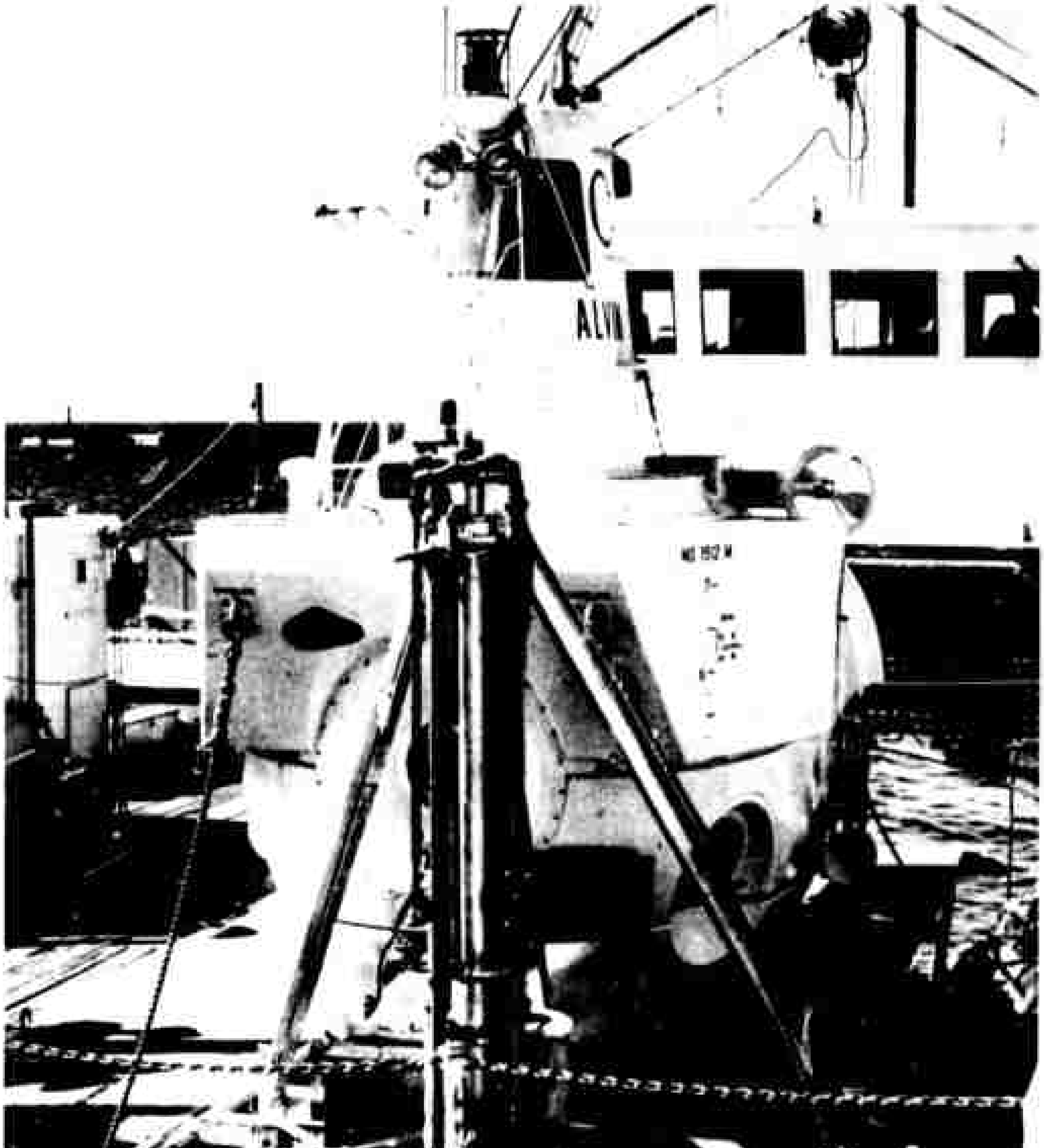

Figure 4. ALVIN/Rock drill coupled together on deck of LULU during Bahama testing (December 1972).

Figure 5. ALVIN/Rock drill on the surface prior to diving for Bahama testing (December 1972).

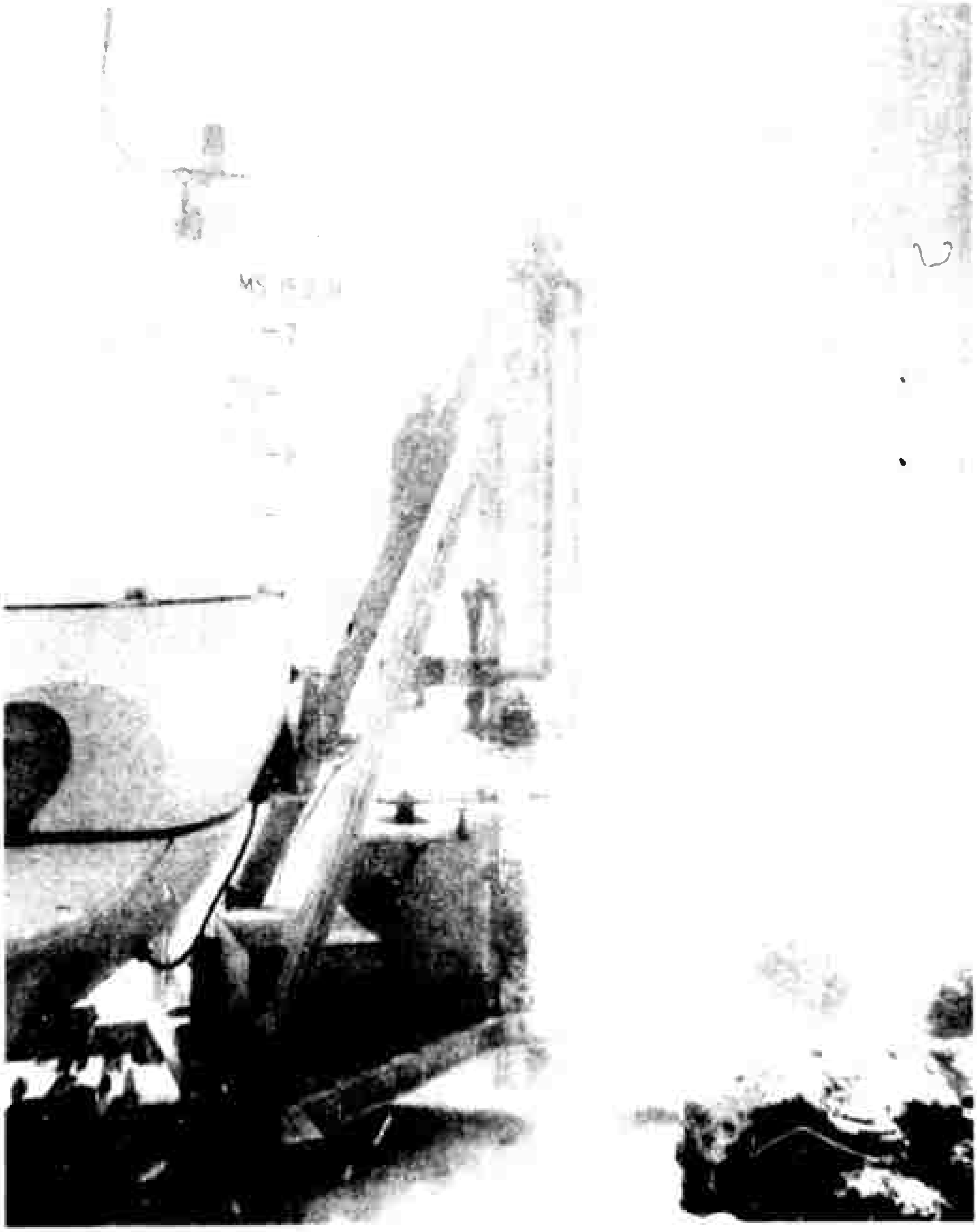

Figure 6. ALVIN/Rock drill submerged in 60 ft. of water during Bahama testing (December 1972).

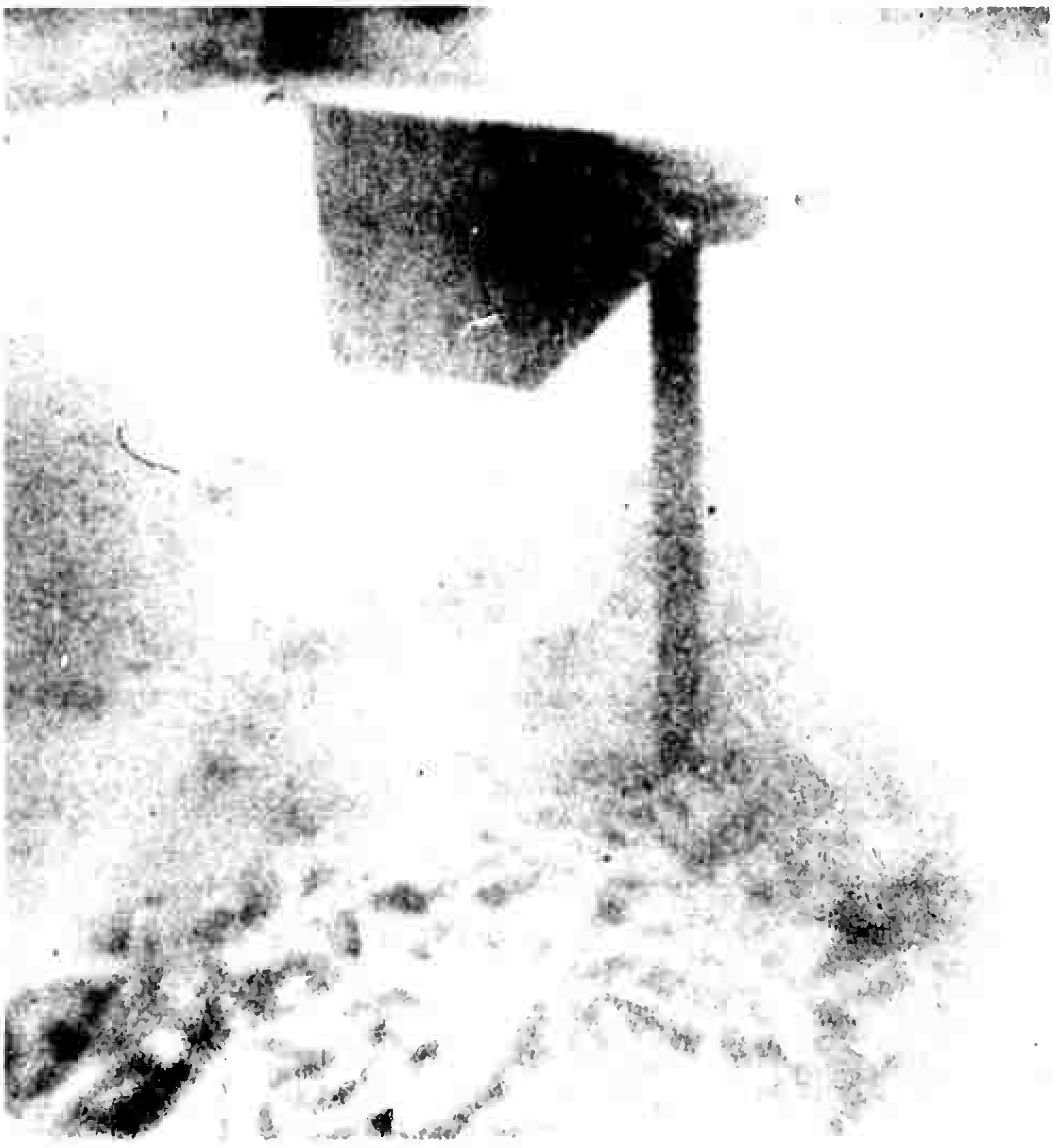

Figure 7. Rock drill core bit penetrating sediment during drilling in Bahama testing (December 1972).

GENERAL SPECIFICATIONS AND DESCRIPTION

Height		9'6"*
Weight	(air)	1,225 lbs.*
	(water)	550 lbs.*
Width	(fore and aft)	60"*
	(beam)	108"*
Operational drill rotation rate		700-1400 rpm*
Battery voltage	(open circuit fully charged)	38.5
	(nominal)	36.0
	(minimum)	30
Battery current	(nominal)	130 amps**
	(maximum)	250 amps
Heater power		50-100 watts
Drilling depth	(maximum rock)	greater than 1 meter
	(sediment overburden)	up to 1 meter
Maximum operating depth		greater than 12,000 ft.
Drill bit size		XRT
Drilled hole size (diameter)		1.155 in.
Core size (diameter)		.735
Drill bit type		Diamond set 25-40 stones per carat
Core barrel		7 ft. rigid double tube
Drilling fluid flow rate		1-1½ gpm
Drilling rate	(sediment)	Highly variable**
	(hard rock)	3-6 in/min**
Core barrel retraction rate		3 ft/min**

* These quantities are subject to relatively small (±10%) perturbations with subsequent design modifications.
** Not as yet well determined.

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Development of Equipment for Use
in Deep-Ocean Biological Research

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Development of Equipment for Use in Deep-Ocean Biological Research

Accomplishments to February 1, 1972

Development of all the proposed equipment within year one was not possible for two reasons: a lack of engineering manpower prevented the necessarily extensive design work for the pressure retrieval system from taking place; the project ran out of funds before all on-going work was completed. The status of the units at the end of this time period is as follows:

1. Construction of the Longhurst-Hardy Plankton Recorder System for the DSRV ALVIN was complete enough to permit extensive field testing. Dockside tests of the system apart from ALVIN were performed in late October and early November. The support frame components, i.e., pressure cases, plankton recorders, nets and flow meters were assembled and the frame lowered into seawater aside Woods Hole Oceanographic Institution dock by means of a crane. Each recorder system was operated underwater by the control units from the surface, thus simulating the actual operating procedure from the DSRV. As a result of these in situ tests, several problems in design of electronic components were discovered and corrected. In late November, the system was attached to ALVIN (Figure 1) and tested on two dives in the Tongue of the Ocean off New Providence Island, Bahamas. Dive 1 was to the sea floor at a depth of 1870 m; dive 2 within the water column down to 300 m. On neither dive did the electronics of the system function properly. On the first dive, much of the trouble apparently originated from seawater leaking into the oil-filled quick disconnects which join wire leads from the externally located pressure cases to the control boxes inside the submarine. The resultant shorts caused the loss of other electronic components and failure of the system. Due to inadequate trouble shooting and repair facilities on board R/V LULU, it was only possible to repair one of the recorder units for the second dive. An as yet undefined problem caused its failure on dive 2. Although the LHPR system is not yet electronically operational, the dives demonstrated that operations with system at the sea floor over fairly rugged terrain and in the water column are well within ALVIN's capability.

2. Sediment trap construction was initiated in October and is approximately two-thirds completed. Figure 2 presents a schematic of the prototype trap for use with DSRV ALVIN. The trap is shown suspended above the bottom of the sea floor from an anchor and sonar reflector following emplacement at the location by ALVIN. After a period of weeks to months ALVIN will return to retrieve the trap for return to the surface. The prototype trap has a base 1 m square and a height of 30 cm. Because it is intended that the material collected be studied by examination of biological composition with light and electron microscopes, and of chemical composition by analysis for heavy metals, pesticides and PCB's and organic elemental constituents C, D, D, the interior is subdivided into 16 chambers each 25 cm on

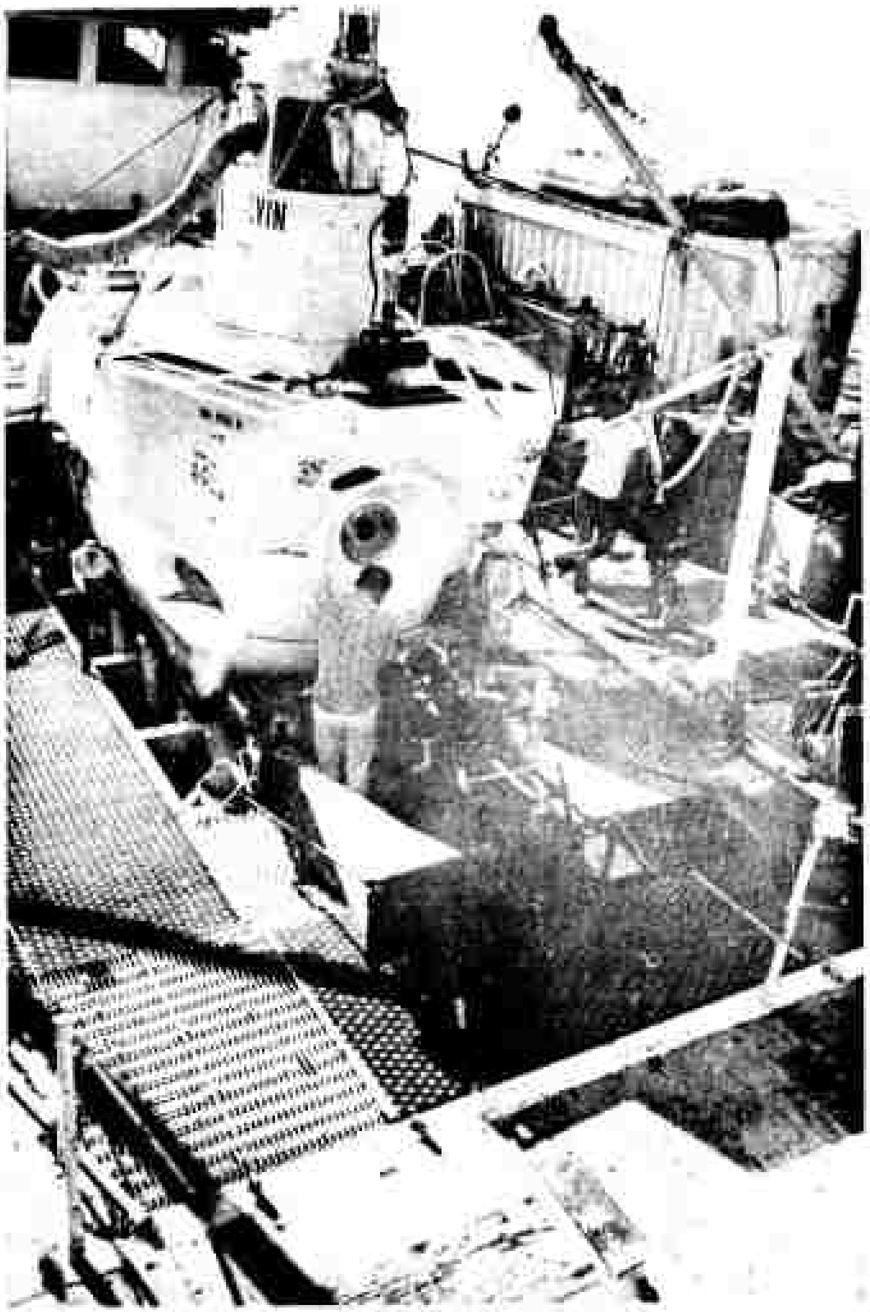

Figure 1. The ALVIN-LHPR system prior to the first test dive on 29 November 1972.

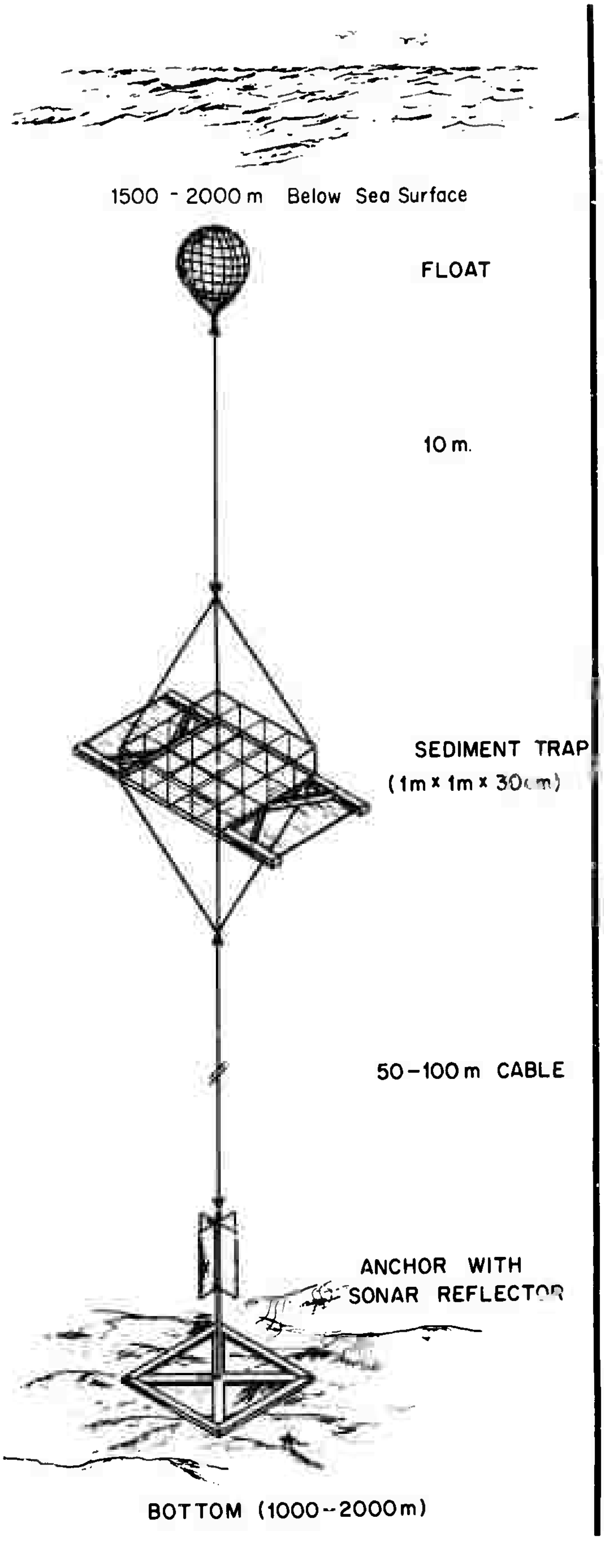

Figure 2. Proto-type sediment trap for use with Deep Submersible ALVIN.

a side to permit collection of 16 separate samples. Collection filters located in the base of the trap will be compatible with the intended biological and chemical analysis. A fine nylon gauze cover will fit over the top of the trap to keep particulate matter from entering the free flooding chambers until it is in place. Similarly, before retrieval, the base portion of the trap will be closed off from the upper portion by means of sliding doors, thus preventing contamination of samples during passage to the sea surface.

3. We designed and constructed two more double bell jars following the basic design used in the first half of the year. One respirometer was equipped with a mechanical injection device for treating the sediment under the bell jars with antibiotics and formalin while the second was outfitted with a telemetry device. Results obtained from the basic respirometer provide total oxygen uptake measurements of the sediment. With the injection system this total uptake can be compartmentalized into bacterial respiration, with the treatment of antibiotics, and chemical demand of the sediments, using a formalin treatment (Smith, 1971; Smith, Burns and Teal, 1971). The antibiotics (streptomycin and penicillin) inhibit bacterial respiration. Formalin poisons the biota leaving only the chemical oxygen demand of the sediments.

The injection system consists of an ampule holder, glass ampule, bread rod and pressure plate (Figure 3). Suspended inside each cylinder is an ampule holder into which the glass ampule is inserted. Between the two ends of the holder the ampule passes through a stainless steel break rod which projects through an O-ring sealed hole in the cylinder top. Welded to the break rod top is a stainless steel pressure plate. When injection is desired the ALVIN arm pushes on the pressure plate causing the glass ampule to break thus releasing its contents into the respirometer. The stirring arrangement over the electrode is sufficient to uniformly disperse the injection fluid.

The telemetry equipped respirometer followed the basic design of the prototype with the exception of the electronic and battery housings. The purpose of using telemetry was to allow a constant monitor of oxygen within the respirometer from the surface ship. This eliminates the need for the recorder and the sphere and allows us to make decisions pertaining to the length of time to leave the respirometer on the bottom and the duration of the injection treatments during the experiment. This is critical since the oxygen uptake by sediments is very variable.

The telemetry transmitter and receiver were designed and constructed by K. Lawson and are described below.

The telemetry transmitter converts either of two electrode currents to an acoustic signal, the frequency of which is proportional to the current magnitude. Zero current is transmitted as 22 kHz while full scale current (about 10 ua, adjustable) corresponds to 20 kHz.

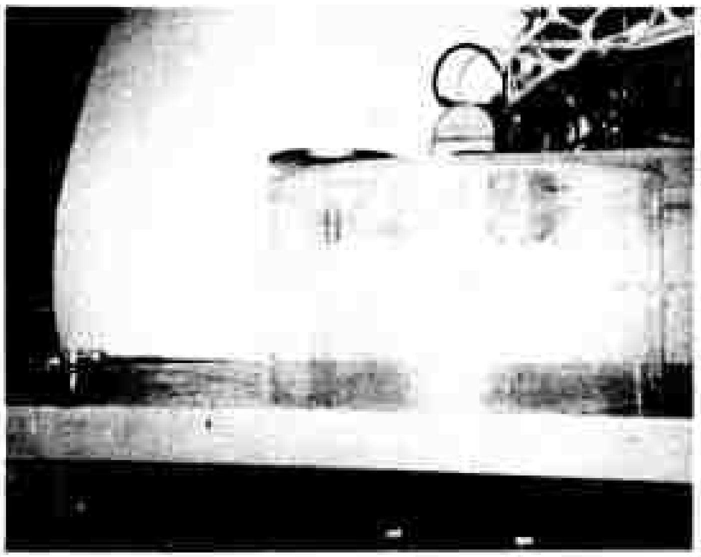

Figure 3. Bell jar injection system for introducing antibiotics and formalin.

Two polarographic oxygen electrodes are operated by transmitter circuitry. The small currents produced by these electrodes are amplified and corrected for temperature effects by the circuitry of board 1 (Figure 4). Board 2 provides the polarization voltage (approximately 1 volt) for proper electrode operation, while selecting the appropriate electrode signal for transmission (Figure 5). Boards 3 and 4 provide a set of logic signals from which derives the transmitted format, or timing sequence (Figures 6 and 7). Board 5 contains a highly linear voltage controlled oscillator (Figure 8). The zero voltage output frequency of the oscillator is periodically reset to 22 kHz by means of sample and hold circuitry referenced to a quartz crystal derived 22 kHz signal. This reference signal is generated in board 6 (Figure 9). Board 7 provides a stable bipolar voltage supply (Figure 10). Board 8 amplifies the voltage controlled output and applies it to an electrostrictive lead zirconate titanate transducer (Figure 11). Power source for the transmitter is a 12 volt, 1 amp/hour rechargeable nickel-cadmium battery.

Power output is 100 milliwatts. Operating life is 48 hours. The transmitter is capable of telemetering the electrode current with an accuracy better than 1% of reading.

The transmitter is constructed in a cylindrical stainless-steel pressure housing using "O" ring end caps. The housing measures 38 cm long, 6.3 cm diameter, with 0.48 cm wall, and was designed for 50% over-pressure at 2000 m of water. All transmitter circuits except the electrodes are contained in this case. The electrode leads are brought out via Mecca bulkhead connectors.

The transducer is mounted to the inside wall of the pressure housing with epoxy cement. This provides an exceptionally rugged instrument.

The telemetry receiver contains a linear voltage controlled oscillator similar to the one used in the transmitter. This oscillator is phase-locked to the incoming signal. The voltage at the oscillator which is required for phase-lock is an accurate replica of the original electrode signal. The timing format allows channel identification.

The transmitted signal is received via a directional hydrophone. After pre-amplification within the hydrophone housing, it is applied to the telemetry receiver proper (Figure 12) where it is filtered and further amplified. This receiver section is a 60 db agc amplifier; its output is essentially constant in use. The amplified output is applied to a phase-locked oscillator (Figure 13). This circuit provides a receiving bandwidth of 40 Hz. The phase-locked oscillator signal is phase shifted by 90° and applied to the sweep acquisition circuit (Figure 14). This circuit detects the presence of a phase coherent incoming signal and interrupts the sweep circuitry. The voltage at the vco input (Figure 13) is applied to a meter amplifier incorporating zero and scale adjustments

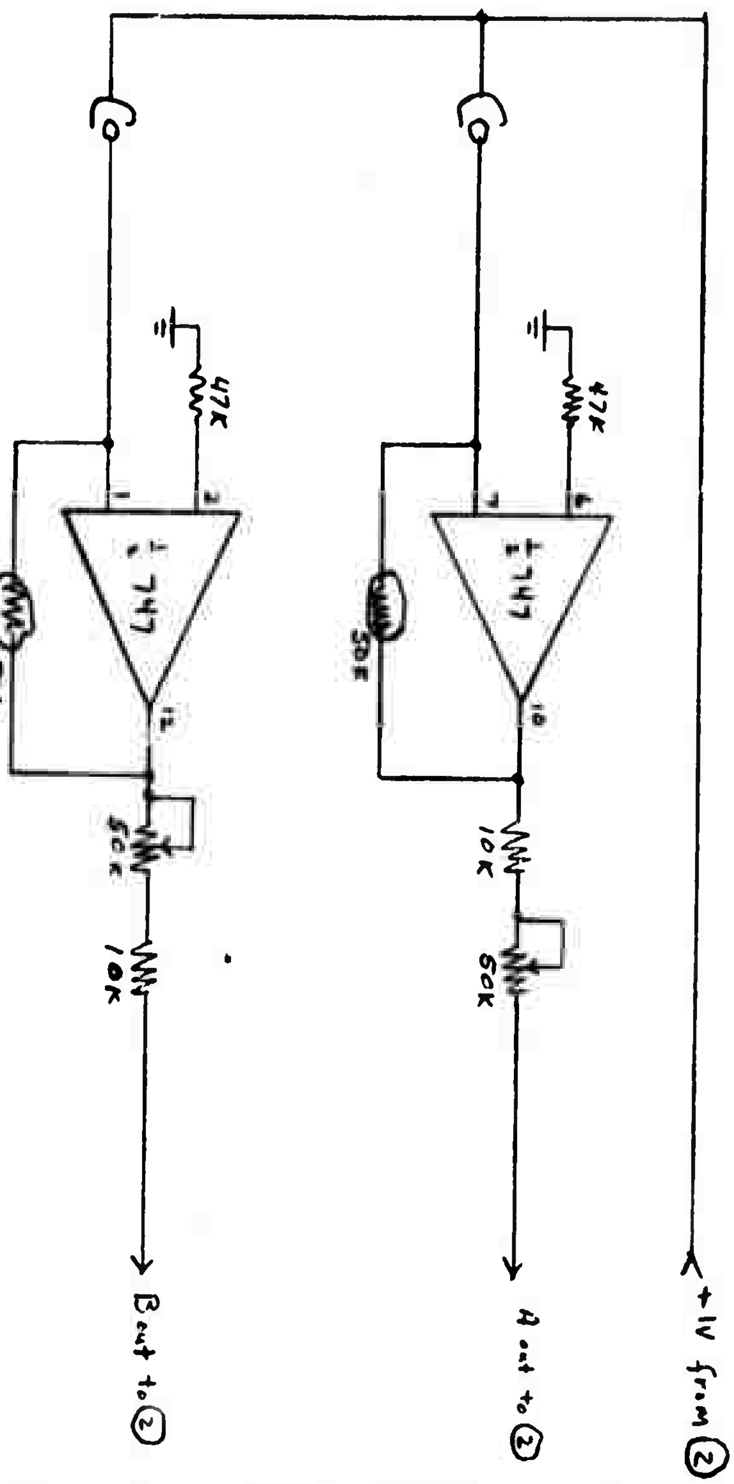

Fig. 4.

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASS. 02543

PROJ.______ BY KL

SHEET 1 OF 10 DATE 10-4-71

TITLE
Two Channel Oxygen Telemeter
(O_2 electrode amplifiers)

SP 11206A

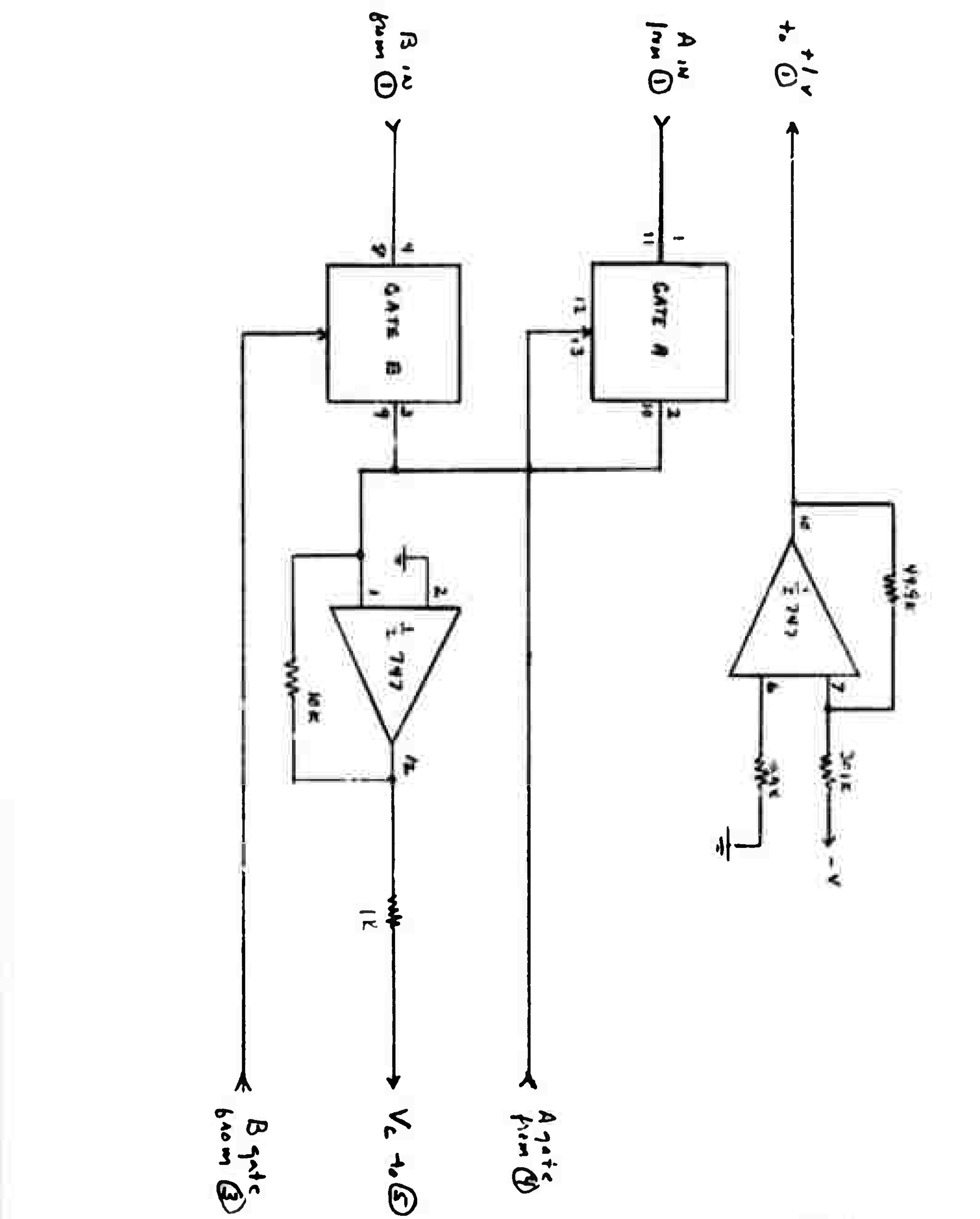

Fig. 5

WOODS HOLE OCEANOGRAPHIC INSTITUTION WOODS HOLE, MASS. 02543	TITLE Two Channel Oxygen Telemeter (channel select, electrode polarizing voltage source, signal amplifier)
PROJ.: ______ BY KL	
SHEET 2 OF 10 DATE 10-4-71	

SP 11208A

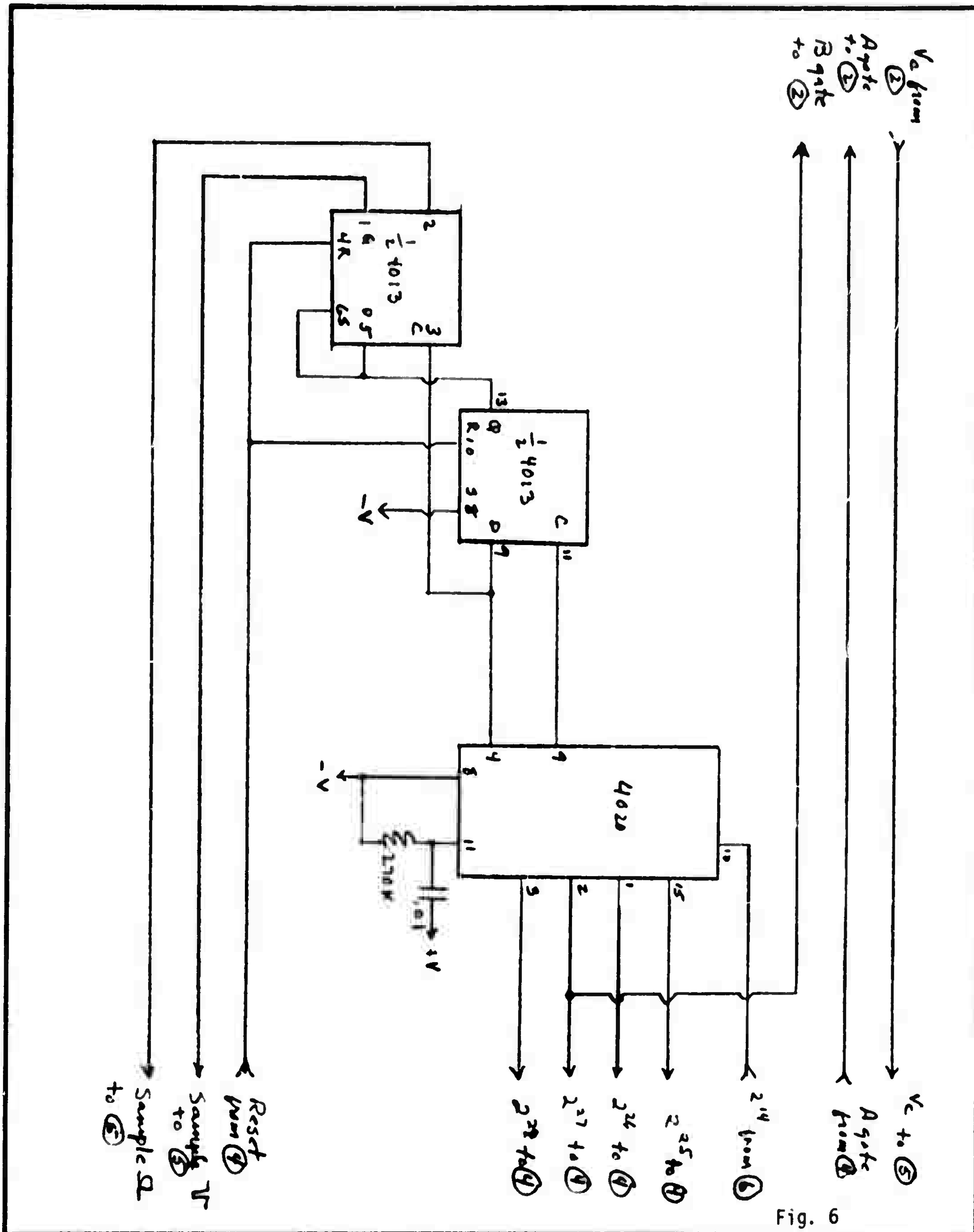

Fig. 6

WOODS HOLE OCEANOGRAPHIC INSTITUTION WOODS HOLE, MASS. 02543	TITLE
PROJ. ______ BY KL	Two Channel Oxygen Telemeter (timing sequence logic)
SHEET 3 OF 10 DATE 10-4-71	

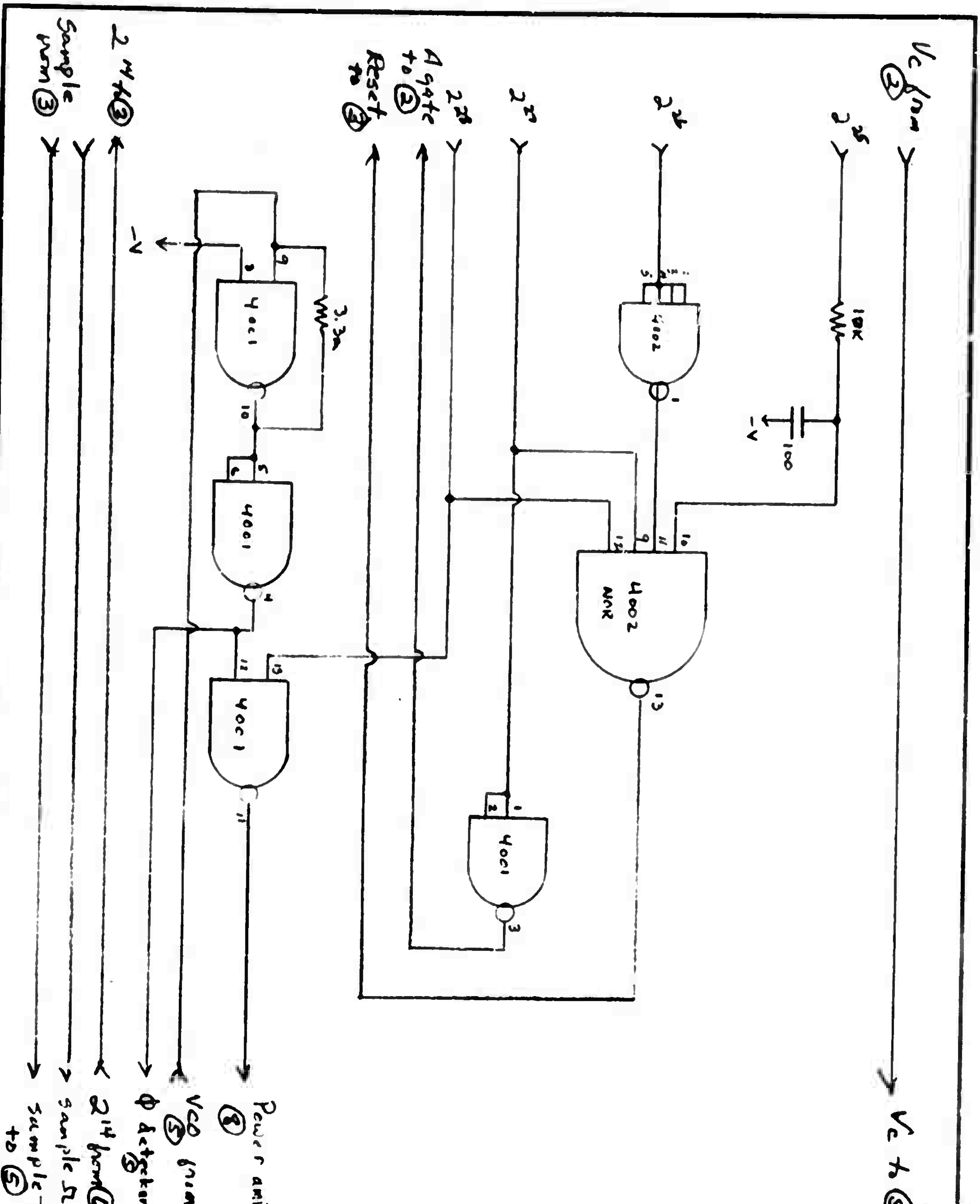

Fig. 7

WOODS HOLE OCEANOGRAPHIC INSTITUTION **WOODS HOLE, MASS. 02543** PROJ. ______ BY KL SHEET 4 OF 10 DATE 10-4-71	TITLE Two Channel Oxygen Telemeter (timing sequence logic and VCO buffer)

SP 11206A

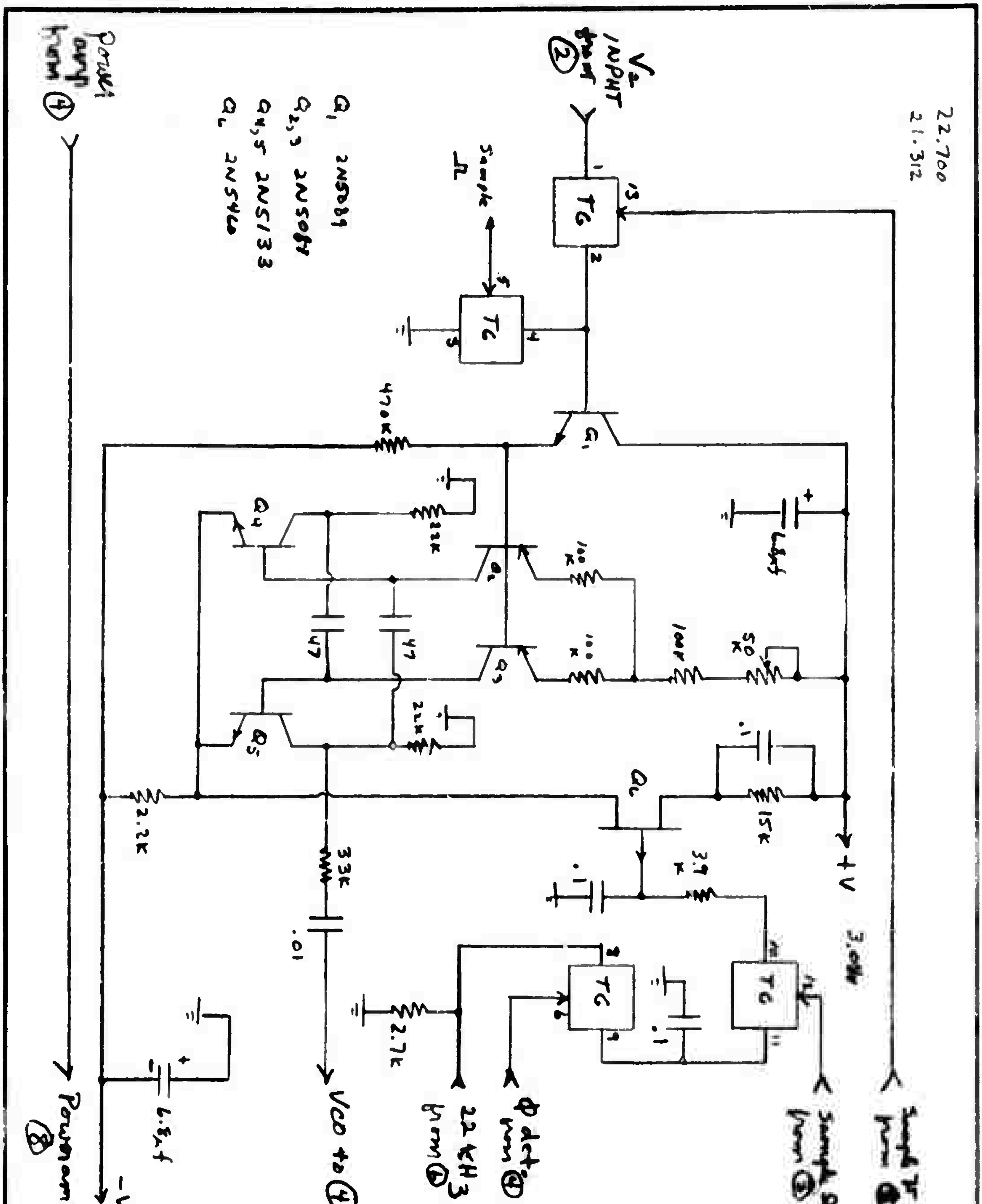

Fig. 8

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASS. 02543

PROJ. ______ BY KL

SHEET 5 OF 10 DATE 9-29-71

TITLE Two Channel Oxygen Telemeter (set-run voltage controlled oscillator)

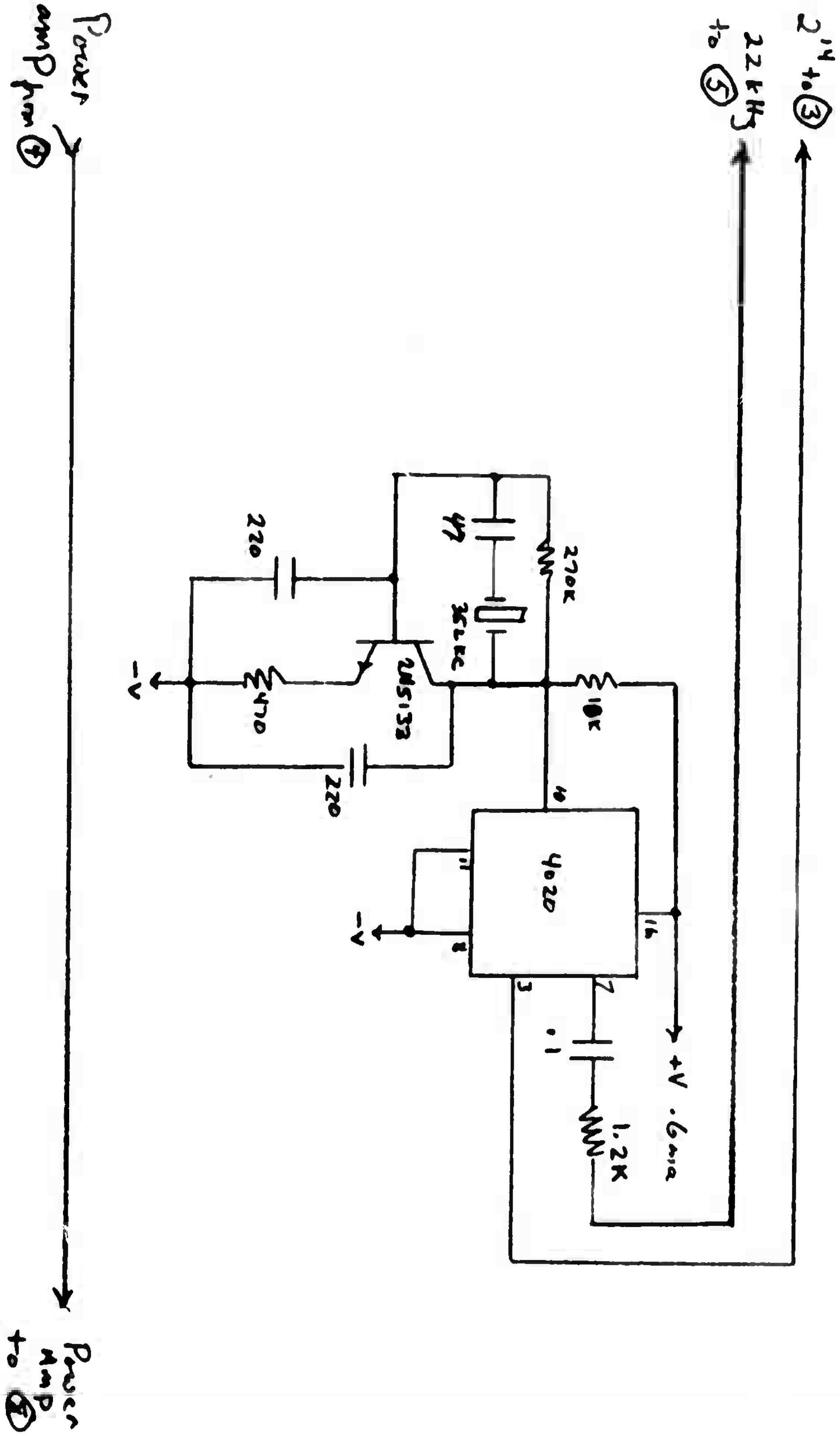

Fig. 9

WOODS HOLE OCEANOGRAPHIC INSTITUTION WOODS HOLE, MASS. 02543	TITLE Two Channel Oxygen Telemeter (crystal controlled 22 kHz reference oscillator)
PROJ. ______ BY KL	
SHEET 6 OF 10 DATE 9-30-71	

SP 11708A

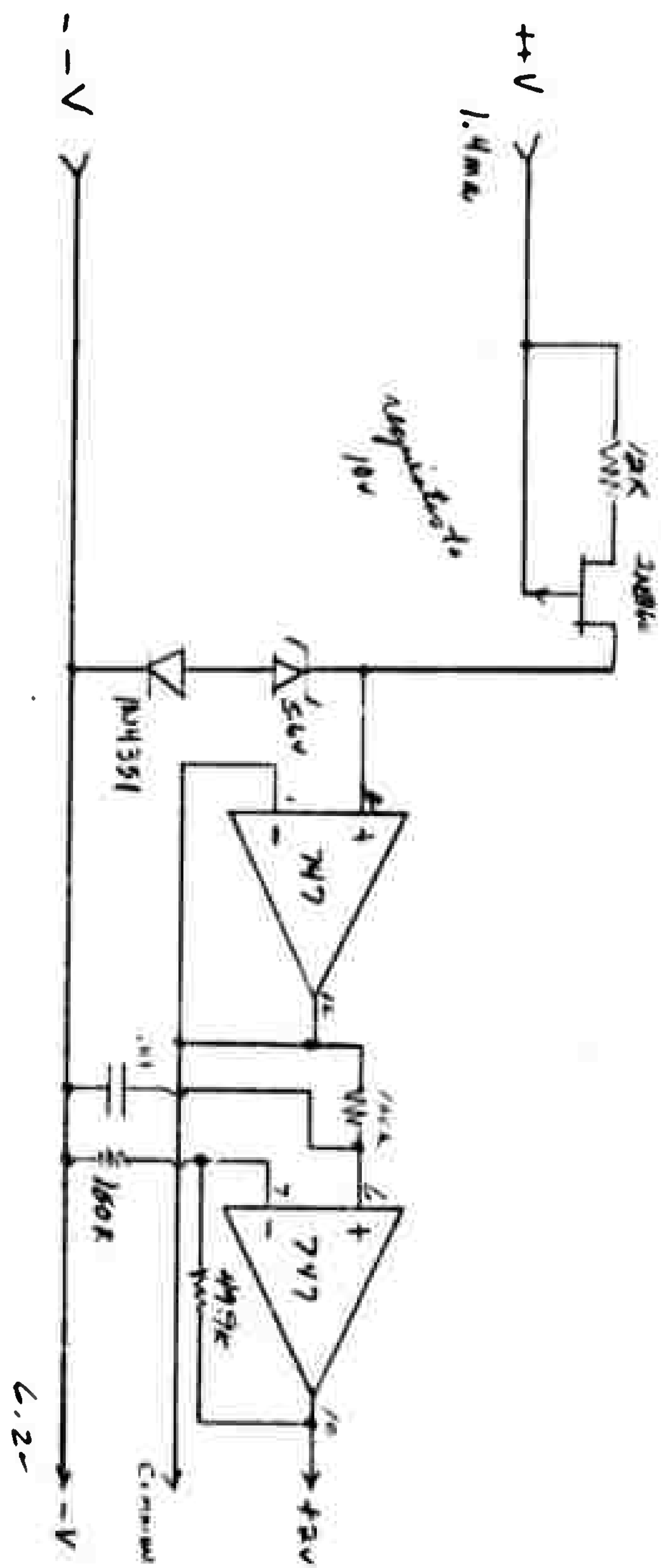

Fig. 10

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASS. 02543

PROJ.______ BY KL

SHEET 7 OF 10 DATE 10-4-71

TITLE Two Channel Oxygen Telemeter
(stabilized power supply)

SP 1120A

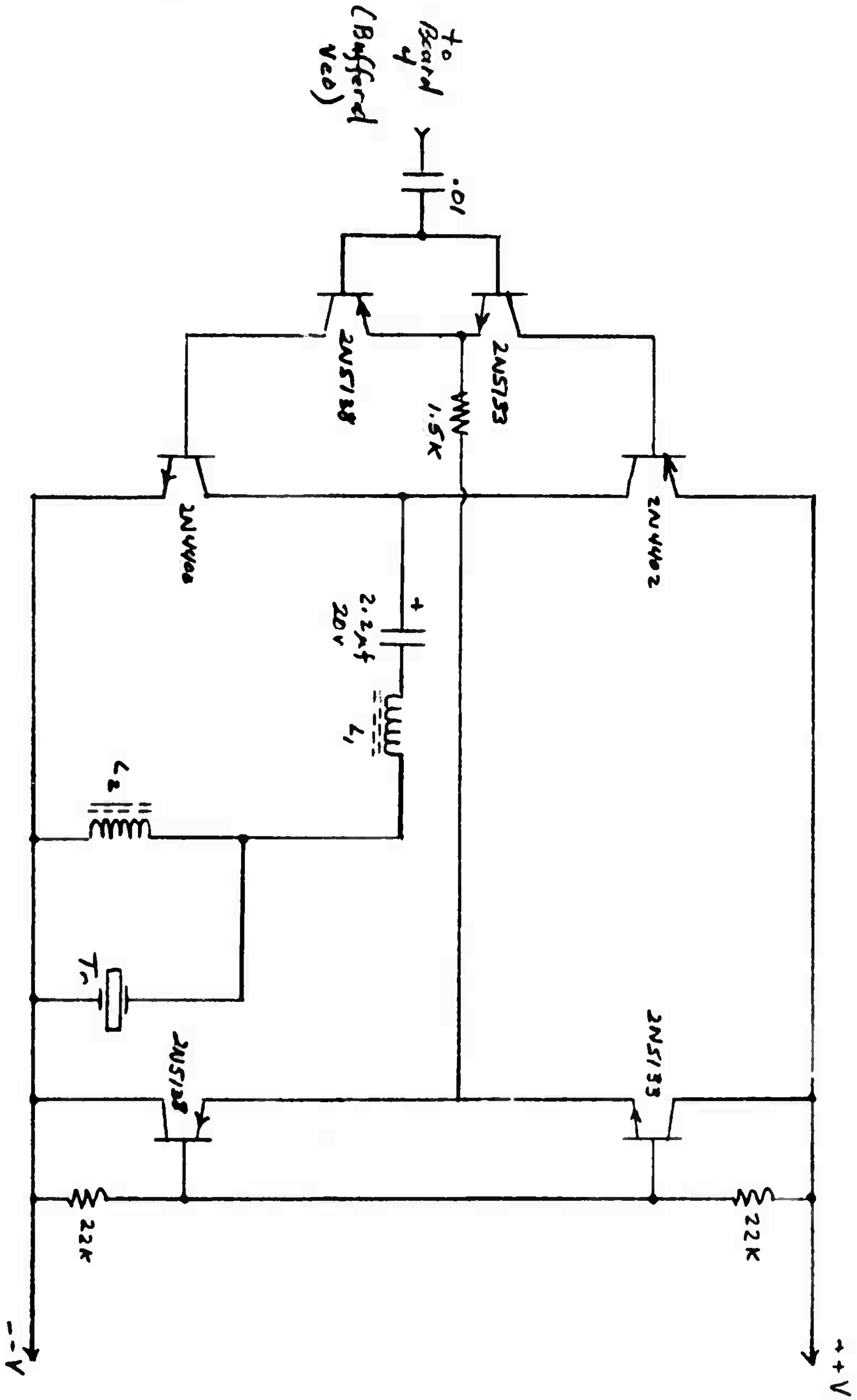

Fig 11

WOODS HOLE OCEANOGRAPHIC INSTITUTION WOODS HOLE, MASS. 02543 PROJ. ________ BY KL SHEET 8 OF 10 DATE 10-4-71	TITLE Two Channel Oxygen Telemeter (power amplifier and transducer matching circuit)

SP 11200A

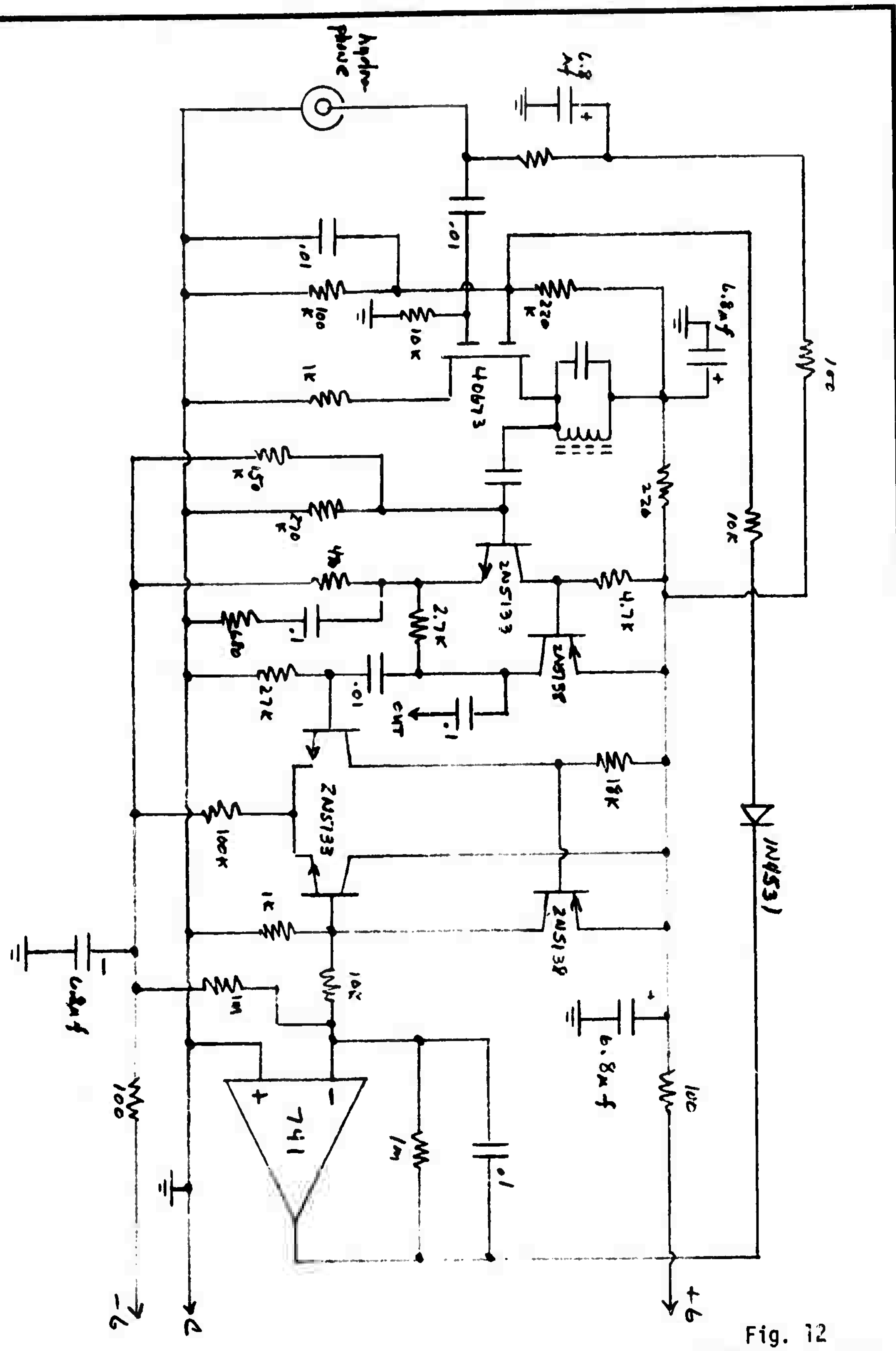

Fig. 12

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASS. 02543

PROJ.______ BY______

SHEET 1 OF 4 DATE 1-7-72

TITLE Phase-lock Receiver
(agc signal amplifier)

SP 11208A

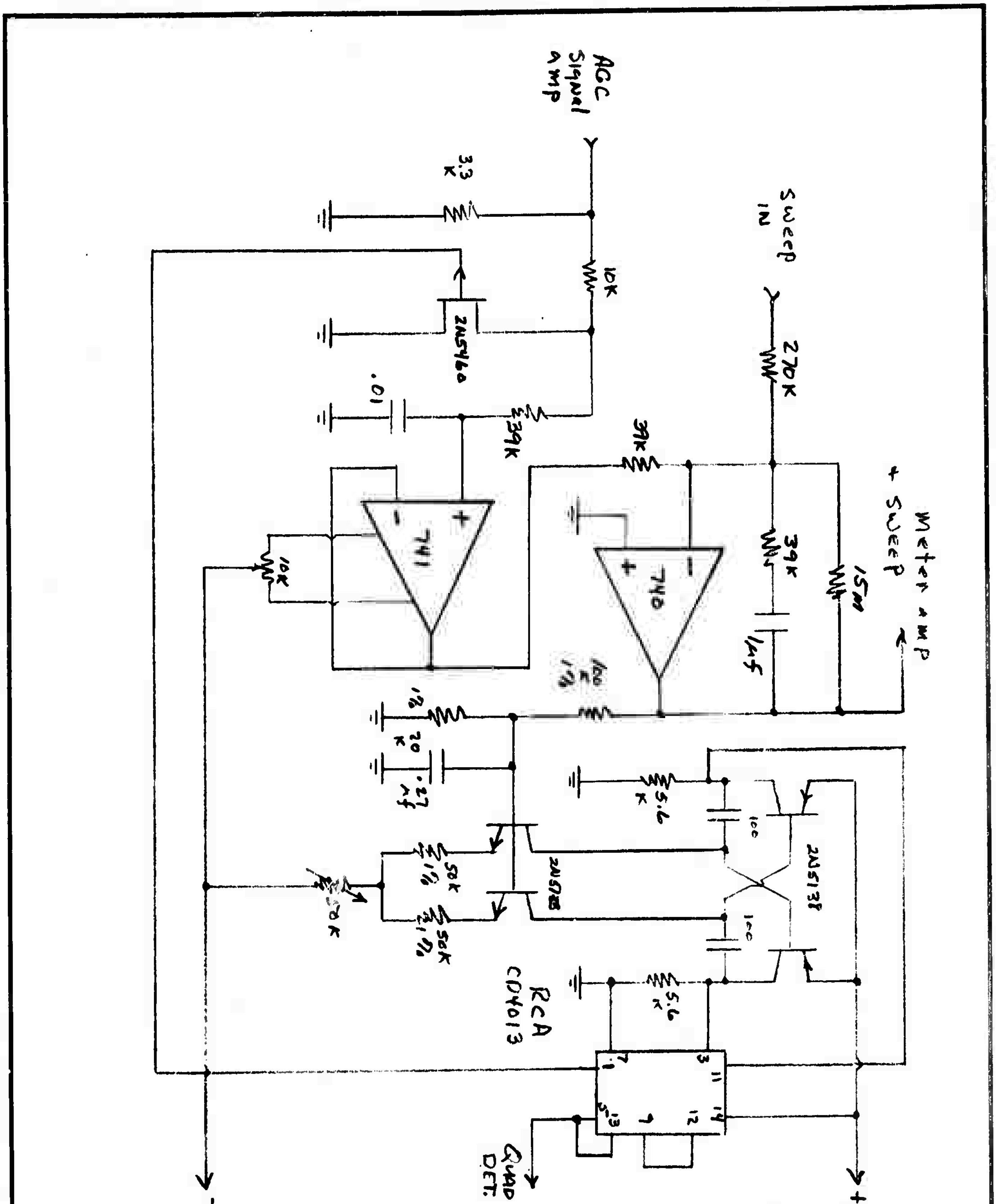

Fig. 13

WOODS HOLE OCEANOGRAPHIC INSTITUTION WOODS HOLE, MASS. 02543	TITLE Phase-lock Receiver (phaseelocked oscillator)
PROJ.______ BY______	
SHEET 2 OF 4 DATE 1-7-72	

SP 11206A

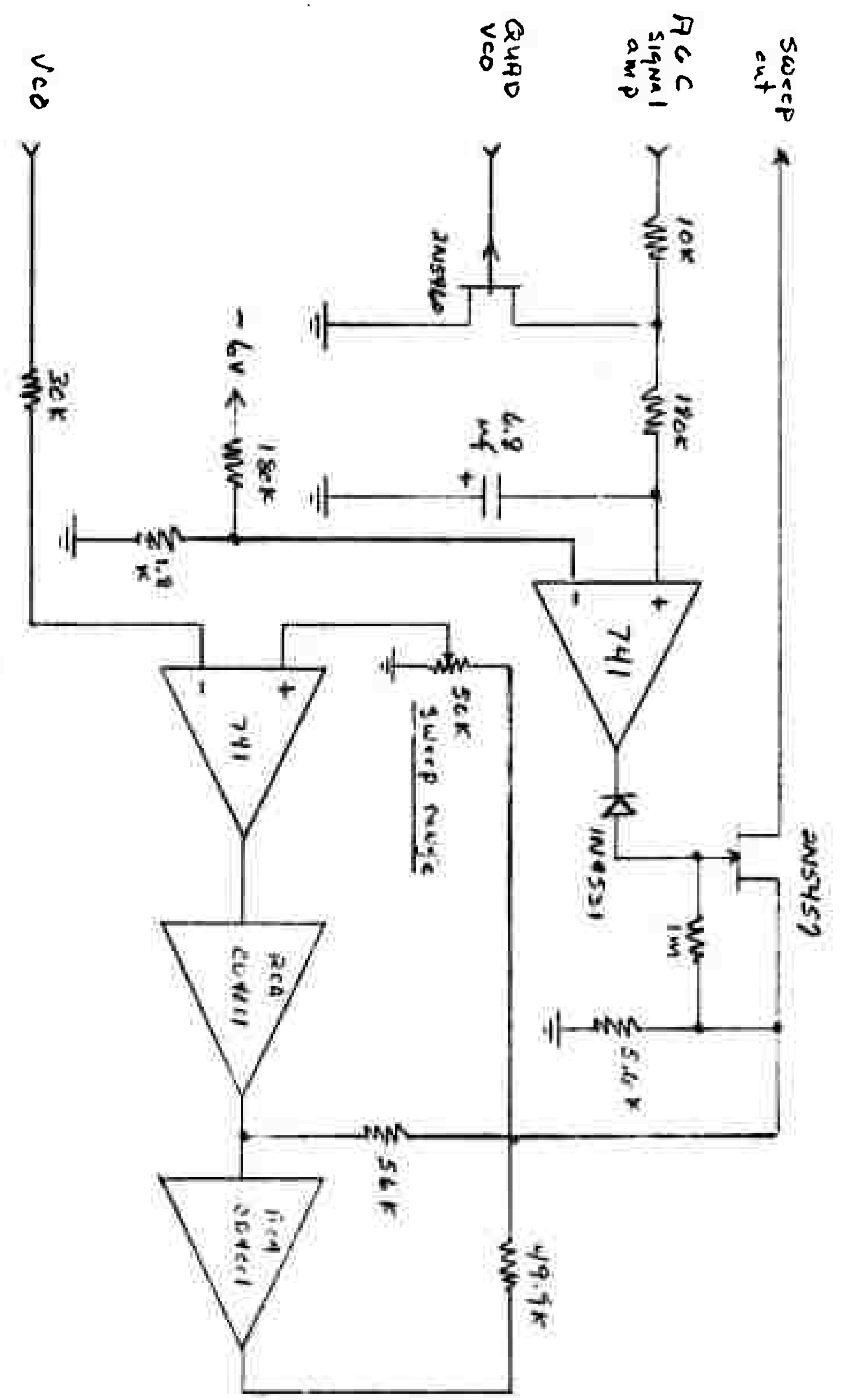

Fig. 14

WOODS HOLE OCEANOGRAPHIC INSTITUTION WOODS HOLE, MASS. 02543	TITLE
PROJ. ____ BY ____	Phase-lock Receiver (sweep acquisition circuit)
SHEET 3 OF 4 DATE 1-7-72	

SP 11200A

(Figure 15). Provision is also made in this section for connection of a strip-chart recorder. Power for the receiver is derived via a stable bipolar 6 volt supply from 12 'C' cells in series.

In August only one short dive was made at the permanent station southeast of Cape Cod. Two double bell jars were utilized on 25 August 1971; one conventional type and the other equipped with the injection system. The bell jar with the injection system was placed on the bottom for only two hours which was insufficient time for an adequate recording but the electronics functioned well. The injection system was not tested but used simply for total uptake measurements. The other respirometer was left on the bottom to be picked up on a subsequent dive, but the weather prevented retrieval. It will be retrieved June 1972 hopefully intact with a good record for a period of up to 100 hours.

The next test dives were made in the Tongue of the Ocean from 11 to 19 November 1971. One test dive was made on 13 November to a depth of 1800 m, but the respirometers were not placed on the bottom because the permanent station markers could not be found. From these abortive attempts we are planning to include an acoustical release for the respirometer so that ALVIN retrieval is not necessary.

Another dive was made on 17 November only to a depth of 600 m. The conventional respirometer was left on the bottom for 22 hours. Oxygen consumption recorded during this period was 202.3 ug at $O_2 m^{-2} hr^{-1}$ which is an order of magnitude less than in situ values obtained in shallow sediments (Pamatmat, 1968; Smith, Burns and Teal, 1971; Smith, Rowe and Nichols, in preparation).

Due to electronic difficulties and minimized diving time we did not test the telemetry apparatus in deep water. However we did successfully test the telemetry electronics within Nassau Harbor using divers.

4. The ALVIN box corers, originally Birge-Ekman box cores (Ekman, 1905), now have been used with SCUBA in Woods Hole Harbor, Buzzards Bay, New York Bight, and in the Tongue of the Ocean. With ALVIN, they have been used in the Gulf of Maine and in the Tongue of the Ocean. Their remaining problem, that of loss from the top of the box after a sample is taken, has been overcome by looping an elastic band over the lids and the wires used to hold the jaws open. When the box is triggered, the band holds the lids down tightly against the box top. We have observed no winnowing since these were initiated. These samplers have allowed us to collect what we believe are record densities for benthic macrofaunal populations (Rowe, 1971) and to capture, with ALVIN, what is believed to be a new genus and a new species of a large, swimming terebellid polychaete worm from 1000 m in the Tongue of the Ocean.

5. The Edgerton elapsed-time 16 mm camera with strobe has been modified by the "Strobe" laboratory at M.I.T. for exposing 50 ft. of film

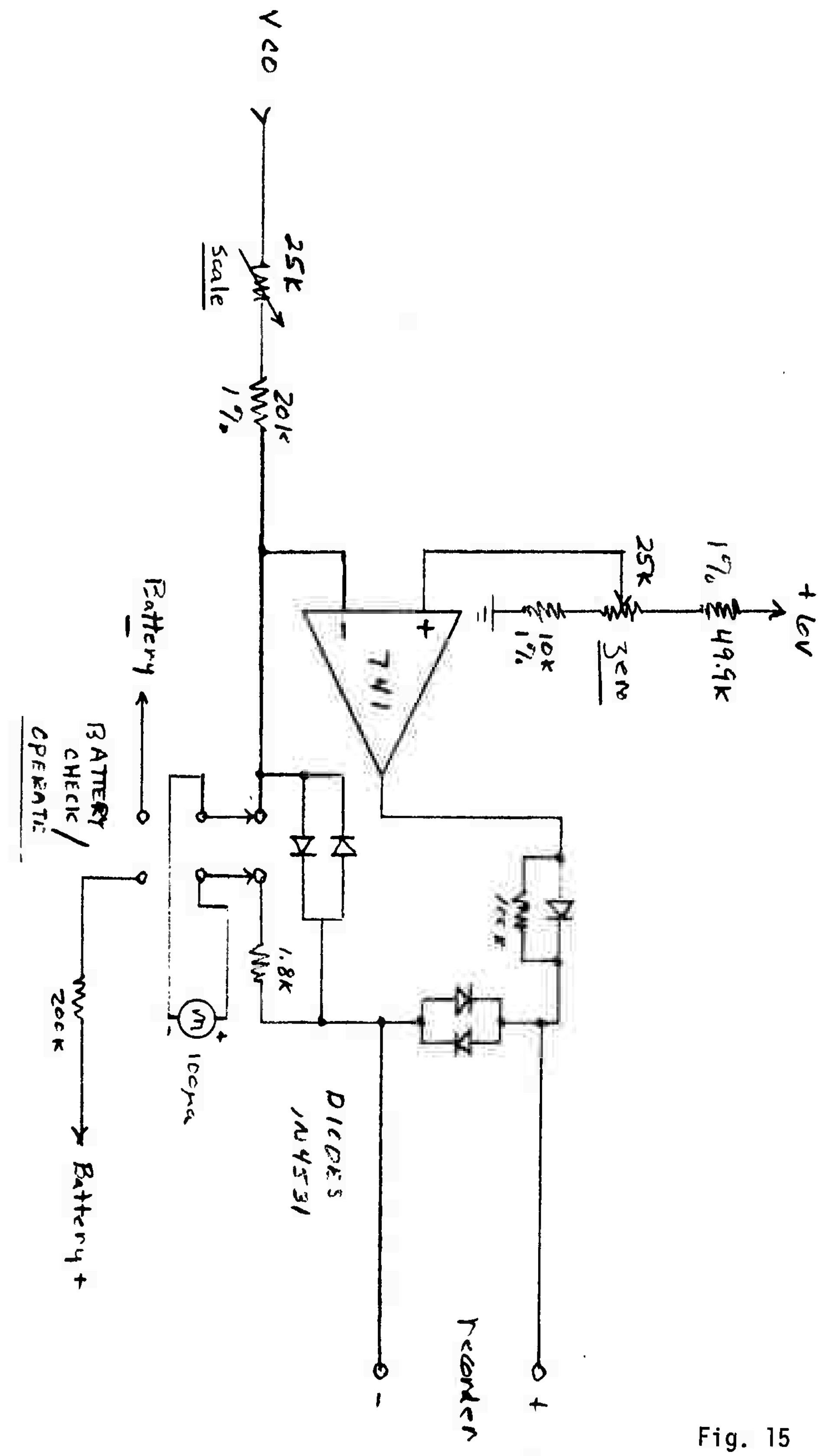

Fig. 15

WOODS HOLE OCEANOGRAPHIC INSTITUTION **WOODS HOLE, MASS. 02543** **PROJ.** ____ **BY** ____ **SHEET** 4 **OF** 4 **DATE** 1-7-72	**TITLE** Phase-lock Receiver (meter amplifier)

SP 11200A

over periods ranging from 12 hours to one week. A 3 m tower-like frame has been constructed to hold the camera in its deep-sea cases. The latter have been fabricated of stainless steel and weigh approximately 175 lbs. each, out of water. They will allow the camera to be used at any depth, when necessary. Initial testing of the system was made of the rates of movement of the epibenthic species of invertebrates and demersal fish.

The remaining problem with the system is to give it approximately neutral buoyancy in the water. This would enable it to be deployed free from the surface with some negative buoyancy; then, with the release of some expendable weight, either by ALVIN or an acoustic release, it would be positively buoyant and rise to the surface.

The second testing of the device was at a depth of 45 ft. in Great Harbor. The system was deployed with R/V ASTERIAS. Seven large glass spheres were attached by line above the tower giving approximately 350 lbs. lift. Divers in the water estimated the system then weighed about 100 lbs. and two divers could, with some difficulty, carry it by walking across the bottom. During this deployment the camera was used at an actual focal distance of 3 ft. and it faced the sediment obliquely at an angle of about 60°. A whole tidal cycle was observed and although there was considerable movement across the surface by large fragments of benthic algae and some movement by starfish, there was very little turbation of the sediments, either by currents, the fauna, or interactions between the two.

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